

ANIMAL BREEDING

LAURENCE M. WINTERS





Digitized by the Internet Archive
in 2025 with funding from
University of Toronto

THE WILEY AGRICULTURAL SERIES

EDITED BY

J. G. LIPMAN, B.Sc., A.M., Ph.D., D.Sc.

DEAN OF AGRICULTURE, RUTGERS COLLEGE AND THE STATE UNIVERSITY
OF NEW JERSEY

ANIMAL BREEDING

THE WILEY AGRICULTURAL SERIES

EDITED BY

J. G. LIPMAN

Soil Management.

By FIRMAN E. BEAR, Professor of Soils, The Ohio State University, Associate in Soils, The Ohio Agricultural Experiment Station. vi + 268 pages. 6 by 9. 33 figures. Cloth, \$2.00 *net*.

Principles of Dairying—Testing and Manufacture.

By H. F. JUDKINS, B.S., Head of Department of Dairying, Massachusetts Agricultural College, Amherst, Mass. xvii + 279 pages. 6 by 9. 74 figures. Cloth, \$2.00 *net*.

Genetics in Plant and Animal Improvement.

By DONALD FORSHA JONES, Connecticut Agricultural Experiment Station, New Haven. v + 568 pages. 6 by 9. 229 figures. Cloth, \$4.00 *net*.

Animal Breeding.

By LAURENCE M. WINTERS, M.S., Professor of Animal Husbandry, University of Saskatchewan. x + 309 pages. 6 by 9. 65 figures. Cloth, \$2.75 *net*.

To be Published Shortly

Agricultural Marketing.

By JOHN T. HORNER, Associate Professor of Economics, Michigan Agricultural College.

Beef Cattle.

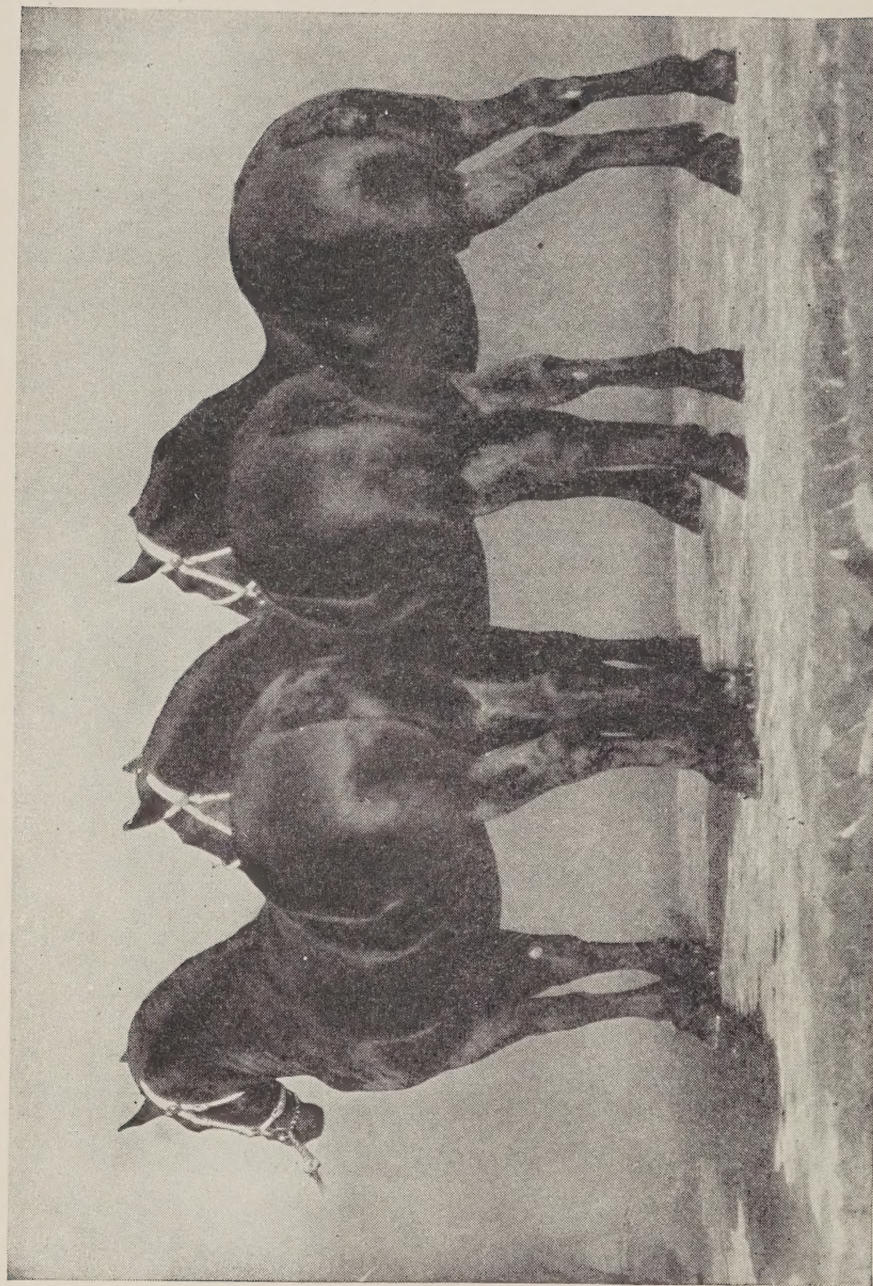
By ROSCOE R. SNAPP, Assistant Professor of Animal Husbandry, University of Illinois.

Small Fruits.

By GEORGE M. DARROW,

Systematic Pomology.

By BROOKS D. DRAIN, Assistant Professor of Pomology, Massachusetts Agricultural College, Amherst, Mass.



Frontispiece.
Laet and his two sons, Jerome and Hesitation—1921 International Grand Champion; Junior and Reserve Grand Champion; First Prize Yearling and 1923 Grand Champion, respectively,—an illustration of “like tends to beget like.” (*Courtesy W. H. Butler.*)

Agrie.
Stock
W

ANIMAL BREEDING

BY

LAURENCE M. WINTERS, M.S.

*Professor of Animal Husbandry
University of Saskatchewan*



200561
15/2/26

NEW YORK
JOHN WILEY & SONS, INC.

LONDON: CHAPMAN & HALL, LIMITED

1925



Copyright, 1925
By LAURENCE M. WINTERS

PRESS OF
BRAUNWORTH & CO
BOOK MANUFACTURERS
BROOKLYN, N. Y.

PREFACE

MODERN industry, of which agriculture is the keystone, is essential to a modern existence. Animal husbandry is the foundation of successful agriculture; and animal breeding is the beginning of all animal husbandry activities. Animal breeding is, therefore, one of the most important of agricultural subjects. It is in recognition of this importance, and with a firm conviction regarding it, that this book has been prepared.

The object has been to select and arrange the subject matter so as to serve as a guide to the student, and at the same time keep in mind the needs of the practitioner who wishes to gain an understanding of the scientific facts and practice of animal breeding. A good understanding of this practice necessarily rests upon a working knowledge of the essential facts regarding genetics. This book has been prepared as a companion volume to "Genetics in Plant and Animal Improvement," which was written by Dr. D. F. Jones.

Although the practice of animal breeding is very old, the science upon which it rests is very young; in consequence, each of the past few years has brought forward many valuable contributions to this subject. It has been the aim of the writer to select those contributions, whether old or new, that appear most valuable, and to incorporate them in this book. In doing this, a most vigorous attempt has been made to give the original references; first, as an aid to the

student who would probe further into some special topic than the space in this work allows; second, that due credit might be given the many tireless research workers, many of whose works, herein reviewed on but half a page or more, represent years of diligent work.

In the choice of illustrations, no attempt has been made to secure representatives of every breed of stock. The writer's intention has been to include such illustrations as would best emphasize the points he wished to make.

The writer takes this opportunity to express gratitude to Dr. D. F. Jones for allowing him to review the manuscript of "Genetics in Plant and Animal Improvement," thus enabling him to bring parts of "Animal Breeding" in closer touch with the companion volume; to the editor for many valuable suggestions; to the publishers for doing everything possible to meet the writer's wishes and to make the book a success; and to the individuals, experiment stations, and publishing companies of the United States, Canada, Great Britain, and Germany who have donated or loaned photographs for the illustrations, without which this work would have been impossible. Individual credit for these is given beneath each illustration.

LAURENCE M. WINTERS

UNIVERSITY OF SASKATCHEWAN

Saskatoon, Saskatchewan

December, 1924

CONTENTS

CHAPTER	PAGE
INTRODUCTION.	1

PART I

THE FOUNDATION

I. THE ECONOMIC FOUNDATION	7
II. THE BIOLOGICAL FOUNDATION—THE CELL	13

PART II

REPRODUCTION

III. REPRODUCTIVE ORGANS, MATURATION AND OVULATION . . .	23
IV. THE OESTRUS CYCLE AND FERTILIZATION	36
V. TWINS	45
VI. SEX	52
VII. GESTATION AND PARTURITION	59
VIII. LACTATION.	69

PART III

HEREDITY

IX. INHERITANCE	81
MENDELIAN INHERITANCE	92
BLENDING INHERITANCE	116
PREPOTENT INHERITANCE.	124
X. VARIATION.	138
CAUSES AND INHERITANCE OF VARIATIONS	146
COMMON BELIEFS REGARDING CAUSES OF VARIATIONS . . .	159

PART IV

THE PRACTICE

CHAPTER	PAGE
XI. THE DEVELOPMENT OF BREEDING	167
XII. CLOSEBREEDING	179
XIII. CROSSBREEDING	194
XIV. GRADING	205
XV. SELECTION	215
XVI. FERTILITY	235
XVII. STERILITY	244
XVIII. ABORTION	254
XIX. CARE OF THE DAM AND NEW-BORN	264
XX. DEVELOPMENT	271
XXI. DEVELOPING A BREEDING ESTABLISHMENT	284
XXII. COMMUNITY BREEDING	293
INDEX	301

ANIMAL BREEDING

INTRODUCTION

ANIMAL breeding implies animal improvement. The latter makes possible larger and more economical production. This is true in spite of the fact that in years of large harvests the very abundance of plant and animal products has a tendency to depress prices, often to the detriment of the producer. But while, for the sake of the producer and consumer, the improper adjustment between production and consumption and between supply and demand must and will be remedied, emphasis will always be laid on the efficient production of efficient plants and animals. Herein lies the value of breeding, and its benefits will be realized more widely as the understanding of the principles of breeding becomes more generally diffused among the producers of plants and animals.

The population of the world is increasing rapidly. If the present rate of increase keeps up, the world's population will be doubled in sixty years and trebled in a hundred. A larger volume of food will be needed, a volume so large as to tax to the utmost the skill and the energy of the producers. The per capita consumption of animal products in some countries will diminish, but the entire quantity used will increase tremendously and every effort will be made to develop types of animals that will transform, most economically, vegetable into animal food.

Animal improvement is thus a matter of vast importance. It involves far more than the mere use of purebred

sires, more than the use of good individuals, and more than the use of individuals possessing good breeding. It is unfortunately true that entirely too many purebreds have masked under the disguise of being something apart and different because of their having a pedigree. Too often the good individual is a disappointment as a breeder, and too often the well-bred individual is a disappointment both as an individual and as a breeder. Animal breeding attempts to account for these disappointments. It seeks to explain and lay down general rules whereby animal improvement may be accomplished.

Genetics serves as a foundation for the subject of animal breeding. As defined by Jones,¹ "Genetics deals with the changes which take place from generation to generation and the means by which features and traits are reproduced in different animals." By investigation, genetics seeks to account for differences and similarities among individuals springing from related and unrelated stocks. In order that the student may reach a clear understanding of the subject, genetics should be made prerequisite to the study of eugenics and of both plant and animal breeding, for these are but applied genetics. The student who would profit most from the study of animal breeding should first become familiar with the subject of genetics.

The subject matter of this book has been so arranged as to permit its use as a companion volume to "Genetics in Plant and Animal Breeding." A certain amount of overlapping will be found in the two texts. This could not be eliminated, since a reasonably rounded exposition of the subject must be given to the student who has not had the opportunity to take the introductory course. Moreover, it seemed necessary to explain clearly the principles of genetics to the stock breeder who has had no preliminary training

¹ Jones, D. F., *Genetics in Plant and Animal Improvements*, John Wiley & Sons, New York, 1925.

in the subject, as well as to review it for the benefit of the student.

Animal breeding proceeds from a science to an art. It is a science in that, to be properly conversant with its principles, one must have an understanding of the means whereby reproduction and heredity are accomplished. In its practical application, however, it is an art rather than a science (164). For the sake of clarity, it has therefore been deemed advisable to divide the subject matter into four parts: Part I, "The Foundation," which sets forth the necessary economic and biological background; Part II, "The Physiology of Reproduction," the purpose of which is to set forth the essential facts regarding reproduction; Part III, "Heredity," which briefly reviews some of the subject matter pertaining to genetics proper, and applies genetics specifically to animal breeding; and Part IV, "The Practice," which sets forth the means whereby breeders of the past and breeders of to-day have accomplished and are accomplishing the desired result—animal improvement.

PART I

THE FOUNDATION

CHAPTER I

THE ECONOMIC FOUNDATION

1. The Field.—The ultimate objective of all activity in animal husbandry is the economic production of meats, dairy produce, wool, furs, power, and other animal products useful to man. The field of animal husbandry is divided into three quite distinct phases, viz., (1) breeding, (2) feeding and management, and (3) marketing, or preparing for consumption and retailing. It may seem at a first glance that an important feature has been omitted in the above, namely, "judging," but judging is involved in all three; the breeder, feeder, and buyer must all have an eye for animal form if they would succeed in their various vocations. It is true, in animal production, that the breeder may at times be the feeder as well, and at times the feeder may likewise take upon himself the duties of marketing. Nevertheless, when he does this his work is covering three quite distinct phases.

Animal breeding is the first step in the production of livestock, the problems of reproduction and improvement are in reality the beginning; it is the first step which the breeder of either market or breeding animals has to contend with; it is, therefore, fundamental in livestock production.

2. The Situation.—The practice of livestock husbandry is not recent; historians are quite agreed that the Neolithic people domesticated animals. Even the improvement of animals is not of recent development, for it appears that the ancient Egyptians were quite proficient as breeders,

feeders, and packers. But the modern improvement of livestock, of which we have exact records, is quite recent, having taken definite form early in the eighteenth century with the work of the pioneer of animal breeders, Robert Bakewell, of Leicestershire, England. That was some two hundred years ago. Since then many breeders have come to the fore, and much has been learned regarding the science and art of animal breeding; yet, in spite of all this, we find far too large a percentage of the animals in North America of inferior quality.

Table I shows the proportion of purebreds to the total numbers of livestock in the United States.

TABLE I

PUREBRED LIVESTOCK ON FARMS, 1920 *

Item	Total Numbers	Purebred Number	Purebred Per Cent of Total
Horses	19,767,161	120,540	0.6
Cattle	66,652,559	1,981,514	3.0
Sheep	35,033,516	463,504	1.3
Swine	59,346,409	2,049,900	3.5

* The Field Illustrated, Year Book, 1922, p. 169.

Table I gives only a numerical comparison of purebred to non-purebred animals; and as many grades are excellent animals, and far too many purebreds are in reality scrubs, it gives only a partial illustration of the point in mind—the proportion of inferior to superior animals. It is the purebred blood, however, that is responsible for the good qualities of the good grade; therefore, the above figures bring out the point that we still have a long way to go before we shall have overdone the purebred business. A few days

spent on any of our central livestock markets will reveal, even to the most skeptical, that the general average of our livestock, as marketed, is far too low in quality. In Ontario,¹ which is fairly indicative of Canada as a whole, it is estimated that only about 2 per cent of the cattle marketed are fit for export.

For dairy cattle we are able to get more exact figures, for purposes of comparison, than for any other class of livestock. We, on this continent, have for years held the highest production records per individual cow—at present held by the Eastern Canadian Holstein-Friesian cow, De Kol Plus Segis Dixie, with a yearly record of 1349 pounds of butterfat. Yet, in the matter of average production, we are too far below the average of the civilized nations as a whole, as the figures in Table II reveal.

TABLE II

AVERAGE YIELD OF MILK PER YEAR OF MILK COWS IN
VARIOUS COUNTRIES *

Country	Year	Average Yield of Milk, Pounds	Country	Year	Average Yield of Milk, Pounds
Netherlands.....	1902	7585	Germany.....	1912	4350
Switzerland.....	1914	6950	Canada.....	1911	3779
United Kingdom..	1914	5934	United States....	1920	3627
Denmark.....	1914	5666			

* Pirtle, T. R., A Handbook of Dairy Statistics, U. S. Dept. Agr.

Another interesting factor in the situation, and one that is encouraging to the man interested in livestock production, is that the world's supply of livestock in proportion to human population is relatively low.

¹ Ontario Bul. 281.

While in some classes of stock the proportion of livestock to human population has experienced a slight increase, during the above-mentioned period, and while there has undoubtedly been a qualitative improvement which does not lend itself to tabulation, yet the proportionate supply of animal products is relatively low and has decreased during the period under consideration. Education and civilization are gradually circumfusing the earth, and a high standard of civilization necessarily demands a reasonable supply of animal products.

TABLE III

PROPORTIONATE INCREASE IN THE WORLD'S POPULATION AND IN LIVESTOCK NUMBERS

Description	Date Near- est 1909	Date Near- est 1918	Livestock to Human Popu- lation	
			1909	1918
Population	1,616,000,000	1,699,000,000		
Horses	96,647,854	99,063,628	1- 16.72	1- 17.15; loss
Asses and mules . . .	14,133,955	15,513,173	1-114.33	1-109.52; gain
Cattle	435,551,410	479,187,080	1- 3.71	1- 3.54; gain
Sheep	558,675,104	522,776,112	1- 2.89	1- 3.25; loss
Goats	93,516,840	92,883,241	1- 17.28	1- 18.29; loss
Swine	140,052,328	173,319,879	1- 11.53	1- 9.08; gain
Total livestock . .	1,338,577,491	1,382,743,113	1- 8.28	1- 8.13; loss
Gain in animal numbers		44,000,000		
Gain in human population		83,000,000		

3. The Problem.—The farmer's business is to furnish the materials for the food and clothing of man. In this business, animals play no small part, as it is through them that the materials unfit for direct human consumption are transformed into products useful to man.

With the continual relative decrease in our agrarian population, it becomes increasingly important that the conversion of rough feeds into human food be carried out with a maximum of efficiency. To do this requires an efficient animal, and efficient animals are only produced by those having a thorough understanding of the fundamental principles and practice of animal breeding.

The individual farmer's problem is to provide himself and his family with a maximum of the necessities and comforts of life, and these must be attained through financial profits. That good livestock helps to solve this problem is indicated by the results (Tables IV and V) of a business survey covering 351 dairy farms in Oxford County, Ontario, for the year ending February 28, 1919.²

TABLE IV
GOOD LIVESTOCK AND LABOR INCOME

Quality of Livestock Per Cent of Average	Number of Farms	Feed Bought	Labor Hired per Farm	Labor Income
Under 71	35	\$206	\$425	\$14
71- 80	34	140	354	761
81- 90	48	231	425	948
91-100	61	233	446	1310
101-110	51	266	417	1498
111-120	31	296	368	1610
121-130	27	338	549	1872
Over 130	40	422	433	2047

Table IV demonstrates that a comfortable labor income and good livestock go hand in hand; Table V, on the other hand, indicates that good livestock is even more vital, for the best financial results, than good crops, but that for the best results the two should be coexistent.

² Leitch, A., Ontario Bul. 281.

TABLE V

COMPARATIVE EFFECTS OF GOOD CROPS AND GOOD LIVESTOCK ON AMOUNT
OF LABOR INCOME

Farms with	Poor Livestock		Medium Livestock		Good Livestock	
	Number of Farms	Labor Income	Number of Farms	Labor Income	Number of Farms	Labor Income
Poor crops.....	39	\$449	36	\$1335	20	\$1398
Medium crops....	68	674	50	1398	54	1909
Good crops.....	20	786	26	1473	25	2134

It should be distinctly understood and always borne in mind that the true measure of success in animal breeding is not quantitative but qualitative.

CHAPTER II

THE BIOLOGICAL FOUNDATION—THE CELL

4. Importance.—Since all organisms are built of cells, the cell furnishes the firm foundation for the study of morphological units. The study of animal breeding as well as that of animal nutrition must, therefore, take the cell as its starting point. The “cell theory” has furnished a definite biological basis for inheritance.

5. The Cell Theory.—Schliden and Schwann, in 1838, introduced the cell theory, which is that all living organisms are composed of cells.

The term “cell,” however, is due to Robert Hooke, who, as early as the middle of the seventeenth century, observed minute structures in cork, which he called cells. The term is an unfortunate one, as it really means a hollow chamber. Gradually, science has been revealing the mysteries of the cell. The living cell is not a hollow chamber but a mass of protoplasm, with or without a cell wall. Within the protoplasm is a minute body of spherical form, which is called the cell nucleus. These—the protoplasm and its nucleus—are the essential components of a living cell.

All the higher organisms are made up of cells. They are the units of construction and destruction. We know definitely that they have not arisen like crystals, but from preexisting cells. The cell is not merely a part of an organism; it is a physiological whole, embodying all the mysteries of life. In the simpler forms of life, all the functions are carried on in one cell. In higher organisms, we find groups of cells or certain organs of the body performing

certain functions, as the lungs, heart, liver, etc. A detailed examination reveals that these organs are composed of groups of similar cells; consequently, it is to the cell that all investigation of the animal body finally drives us. In the muscle cell lies the problem of locomotion; in the epithelial cell and the leucocyte (white corpuscle) lies the problem of resorption; and in the reproductive cell lies the problem of reproduction and inheritance.

We look to the cell as the unit of construction, but all the life of all organisms started as one cell. From one fully developed and fertilized cell, we may trace the development not only of such organisms as the amoeba, but of the horse, the ox, etc. From that one cell, we find an outgrowth of many cells, arranged in groups which are very diverse in their functions; therefore, we cannot look to the cell as the ultimate unit of construction. To understand the physiology of reproduction and heredity, we must first understand the cell, cell division, and cell growth.

6. Cell Structure.¹—The cell is simply a mass of protoplasm containing a nucleus (Fig. 1-A). Both the protoplasm and its nucleus have arisen from the division of the corresponding components of a previous cell.

The cell is made up of two main parts, namely, the cytoplasm or cell body, and the nucleus. The cytoplasm is all that portion of the cell outside the nucleus. In its simplest form, the cell is a rounded mass of protoplasm, and is found as such in one-celled forms; this is also the characteristic form of the egg cell in higher animals. In higher animals and plants, however, cells of various shapes are found; this is due to unequal pressure and to the movement of other cells making up the animal body.

In higher animals and plants, many cells have a cell wall, but it is by no means an essential part of the cell; it is simply formed from a hardening of the exterior of the cell body. The centrosome is another body generally found

¹ Wilson, *The Cell in Development and Inheritance*.

in the cell; it is concerned with the mechanism of cell division.

Other bodies often present in a cell are food granules. These granules are undoubtedly food products that have not as yet been absorbed, or are products of excretion. They play an active part in the metabolism of the cell, but until metabolized, they are not a part of the cell, and may therefore be looked upon as subsidiary bodies.

7. Protoplasm.—Protoplasm is a general term for all matter endowed with life. It is present in every living cell. Huxley defined protoplasm as, “the physical basis of life.”

It should always be borne in mind that “protoplasm” is a biological term rather than a chemical one. It is impossible to say just what protoplasm is, for protoplasm is alive, and so long as it is alive it cannot be analyzed. Upon death, it breaks up into its component chemical elements; it is then no longer alive, hence not protoplasm.

Living and non-living matter are very different. The known differences between them as set forth by Davenport,² are:

“1. Living matter is endowed with a mysterious force called life.

“2. Matter so endowed has a much more complicated chemical composition than has non-living matter, or than can be maintained after the life principle has departed. Living matter at death, therefore, breaks up (or down) into ordinary chemical compounds. The true constitution of living matter cannot, therefore, be determined by any known methods of analysis, which reveal only the elements but not their exact relations during life.

“3. Matter endowed with life is able to appropriate to itself other outlying matter and to increase its bulk through growth.

“4. This growth is not of bulk merely, but it is attended

² Davenport, E., Principles of Breeding, p. 142.

by differentiation, so that one part is distinctly different from another.

“5. As growth proceeds bits of this bulk are thrown off, each of which constitutes a new individual capable of independent existence,—reproduction.

“6. The new individual is *substantially*, but never exactly, like the one from which it arose, and here lie the chief mysteries of breeding. In reproduction there are no duplicates.”

The vital characteristics of protoplasm are its capability of movement, irritability and power of assimilation and of reproduction.

Protoplasm is composed of three intrinsic materials, viz., reticulum, cell-sap, and microsomes. The reticulum forms a network which is filled with the cell-sap, and the microsomes, which are minute granules, are distributed along the lines of the network.

8. The Nucleus.—The nucleus is a body enclosed in the cytoplasm. It is the center of the cell's constructive activities. In a cell devoid of a nucleus, the only possible activities are destructive ones, decomposition. The nucleus is the regulating center of cell activity; it is the principal factor in growth, development, and the transmission of precise attributes from parent to daughter cell or generation to generation. Growth results from cell division, and the nucleus apparently gives the necessary impetus for cell division; for it is essential, in cell division, that a portion of the nuclear material of the parent cell pass into the new cell. The new cell in turn divides and thus growth goes on.

The typical nucleus is oval; but it may be rod-shaped, bent like a horseshoe, tree-shaped, or in the form of a rosary. It exhibits two distinct phases: the vegetative or resting stage, and the active stage during which cell division and reproduction occur.

9. The Nuclear Substance.—A typical nucleus during the vegetative stage is constructed as described below:

(1) A nuclear wall surrounds the nucleus, differentiating it from the cell body.

(2) The reticulum, appearing as an irregular network, is of primary importance in nuclear activities and it is made up of the (*a*) chromatin and (*b*) achromatin; apparently, the chromatin is the only or chief substance transmitted from parent to daughter cell and from it all other material may be formed. Without a doubt, it is the most fundamental substance concerned in the growth and inheritance of living organisms. Chromatin may appear in the nucleus as scattered granules, as a single deeply stained mass, or as a network closely associated with the achromatin. It received its name, chromatin, from the fact that it takes a deep red stain when treated with certain reagents.

(3) The ground substance is a clear fluid which fills the chromatin network and is differentiated from it by not being stained with ordinary reagents.

(4) The nucleoli are generally, but not necessarily, present. It is believed by some that the nucleoli are by-products of the activities of the nucleus, but their nature and functions are not clearly understood.

10. The Centrosome.—Closely associated with the nucleus and also lying in the protoplasm is a special body, the centrosome. It is probable that it is a derivative of the nucleus, possibly a part of the achromatin which has left the nucleus, or possibly a second nucleus which has lost the chromatin. Its function is, clearly, the control of cell division, as it controls both the division of the nucleus and that of the cell itself.

11. Growth.—Growth is not merely an accumulation in bulk of the existing cells; it is accomplished by cell division. This division is qualitative as well as quantitative. It is from the fertilized egg cell that such complex organisms as horses, cows, etc., are developed. The fertilized egg cell results from the union of two germ cells which carry with them all that either parent can transmit to the off-

spring. By repeated cell divisions, the fertilized egg passes on to every other part of the body a part of its substance, and thus inheritance is transmitted. Cell division is, therefore, not only fundamental to growth and development, but it is also the medium by which heredity functions.

12. Cell Multiplication.—Cells multiply by direct and indirect division. The most typical, and that which is of chief concern in animal breeding, is indirect division, or mitosis.

Previous to mitosis, the cell passes through a resting stage called the vegetative stage. This is followed by a period of great activity, the result of which is two cells in place of one. Wilson³ has described the different phases of mitosis as (1) prophase, (2) metaphase, (3) anaphase, and (4) telophase, and his discussion of the same is closely followed in this chapter.

13. Prophase.—During the resting stage, the chromatin appears as a network. During prophase, the chromatin gradually loses its network appearance, taking on a skein-like form called the "spireme," which is thread like, stains a deep red, and is greatly convoluted.

The spireme breaks up into a number of definite straight or curved rods called chromosomes, and usually the nuclear wall disappears at about this time. Every plant and animal possesses a definite number of chromosomes.

14. Metaphase.—The chromosomes now divide lengthwise, thus allowing an equal division, both qualitative and quantitative; and the two groups move to opposite sides of the cell. There is good evidence that each chromosome is made up of granules (genes) running lengthwise like a string of beads, and that each of these genes represents a definite character or group of characters. Thus, with longitudinal cleavage, these characters are divided as well, hence the qualitative as well as quantitative division. This, then, gives a reasonable physical basis for heredity.

³ Wilson, *The Cell in Development and Inheritance*.

15. Anaphase.—Anaphase is marked by the separation of the two groups of chromosomes, which pass to opposite sides of the cell.

16. Telophase.—In telophase, a complete division of the cell is accomplished, with the formation of two cells in place of one. The two groups of chromosomes rearrange themselves and each becomes the nucleus of its cell.

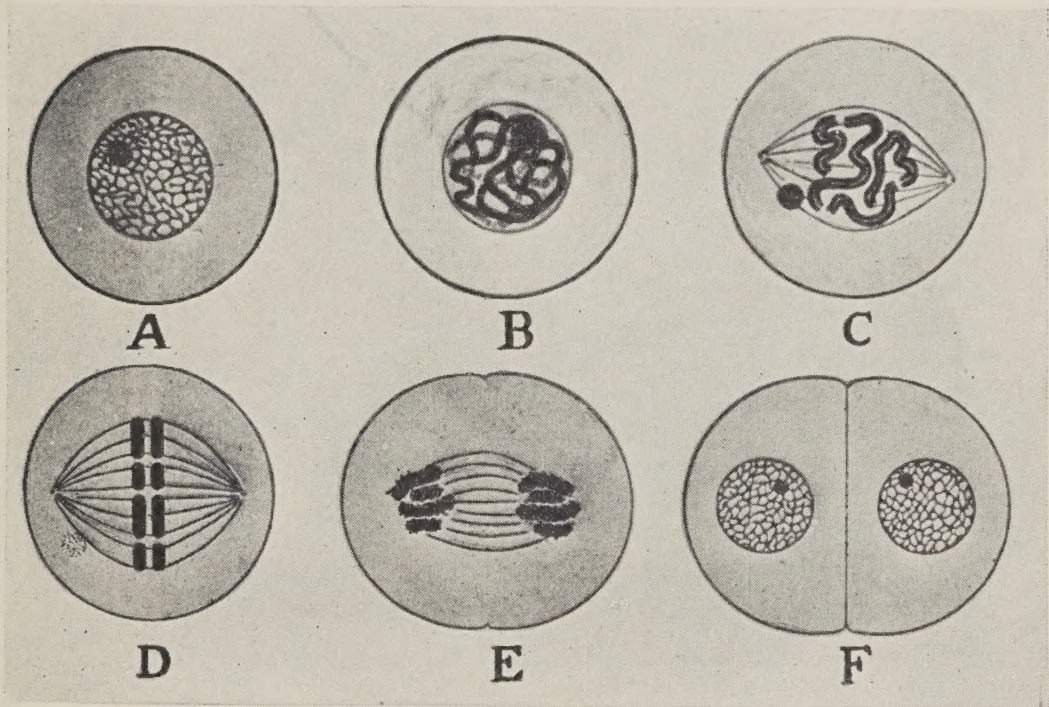


FIG. 1.—Mitosis of the cell having four chromosomes. (From Babcock and Clausen's *Genetics in Relation to Agriculture*, McGraw-Hill Book Co., Inc., Reprinted by permission.)

A, vegetative or resting stage; B, formation of the spireme-thread; C, longitudinal division of the spireme-thread and formation of the chromosomes; D, separation of the chromosomes; E, divergence of the daughter chromosome to form new cells; F, cell division, complete.

17. The Essential Steps.—The essential steps in cell division are:

1. Formation of the chromatin into a spireme thread.
2. Spireme division into chromosomes.
3. Longitudinal cleavage of the chromosomes.
4. Separation of the two groups of chromosomes.
5. Complete cell cleavage.

PART II

REPRODUCTION

CHAPTER III

REPRODUCTIVE ORGANS, MATURATION AND OVULATION

18. Phases of Reproduction.—There are several clearly defined steps or phases in the physiology of reproduction, which may be outlined as follows:

1. Maturation—ripening of the generative cells.
2. Ovulation—extrusion of ovum from ovary.
3. Oestrus—heat period.
4. Coition—mating.
5. Fertilization—union of egg and sperm cells.
6. Gestation—period of pregnancy.
7. Parturition—expulsion of the foetus.
8. Lactation—secretion of milk.

To understand and appreciate the various steps in reproduction, it is first necessary to understand the reproductive organs.

19. Male Reproductive Organs.—The male reproductive system comprises the following organs: (1) testicles, (2) vas deferens, (3) ejaculatory ducts, (4) vesiculæ seminales, (5) prostate gland, (6) Cowper's glands, (7) urethra and (8) penis. (Fig. 5.) The last seven are often spoken of as the accessory generative organs, while the testicles are spoken of as the essential organs; for it is in them that the male's vital contribution to reproduction has its origin.

20. The Testicles.—The essential sexual elements, the spermatozoa, are formed within the testicles; therefore, castration destroys the animal's reproductive powers.

The testicle's make-up, which, for the purpose of clearness, has been arranged in steps, is as follows:¹ (Fig. 2.)

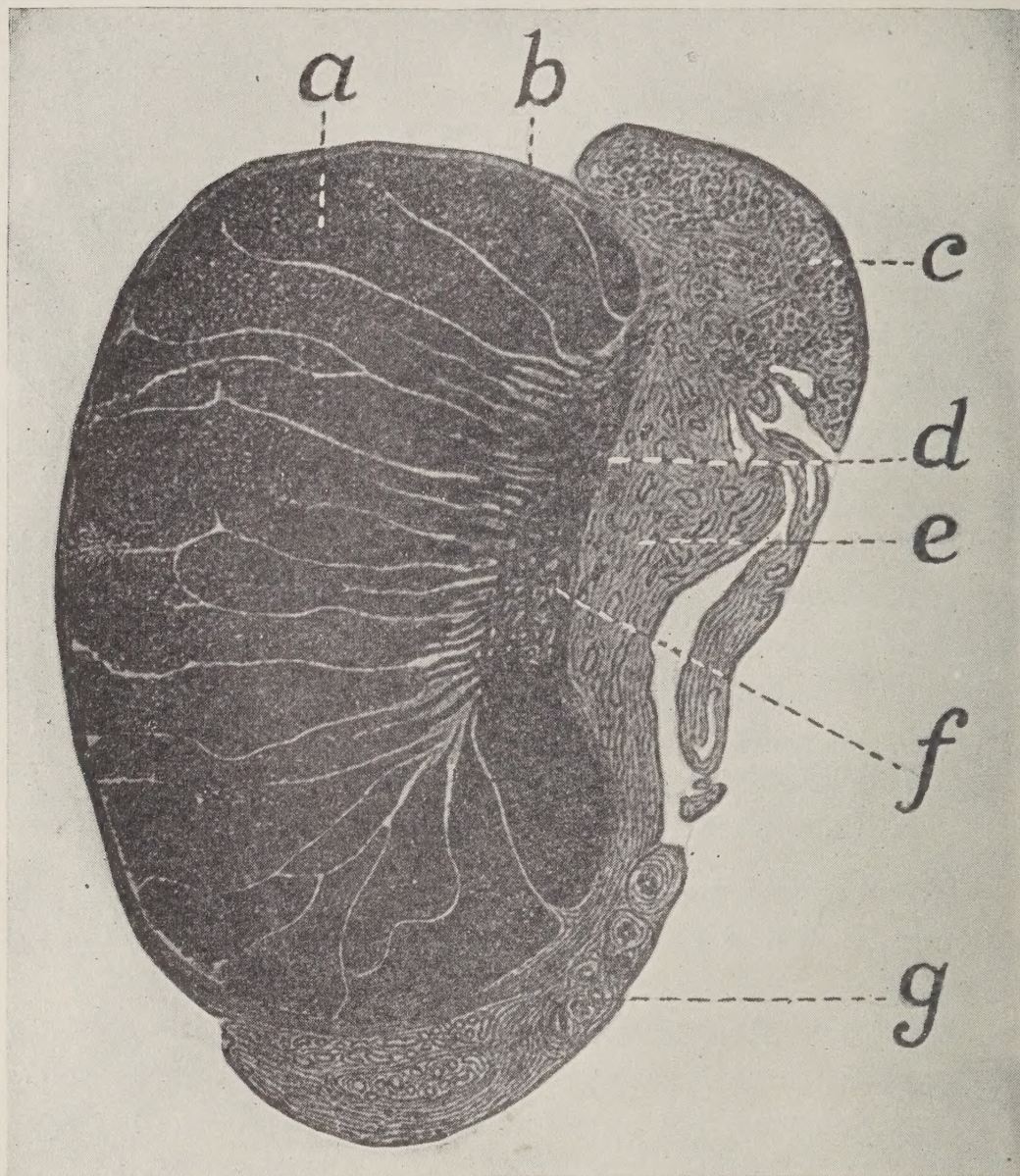


FIG. 2.—Section through human testis and epididymis. (After Bohm and von Davidoff, from Schafer's *Quain's Anatomy*, reprinted by permission.)

a, Glandular substance divided into lobules; *c*, part of epididymis; *d*, rete testis; *e*, body of epididymis; *f*, mediastinum; *g*, section through vas deferens.

- (1) A layer of serous epithelium covers the testicle.
- (2) Just beneath this, a fibrous capsule, rich in lym-

¹ Marshall, Francis H. A., *The Physiology of Reproduction*, p. 159.

phatics, encloses the testis and posteriorly protracts into the interior of the testis in the form of a mass of fibrous tissue called *mediastinum testis*.

(3) Other fibrous processes project inward and divide the glandular substance into lobules.

(4) This glandular substance of the testis is composed of the convoluted seminiferous tubules (tubules producing or carrying semen), two or three of which unite to form a straight tubule which passes into the body of the *mediastinum*.

(5) The spermatogonia (sperm-producing cells) are situated within the seminiferous tubules; they, the spermatogonia, constitute part of the outermost layer comprising the seminiferous tubules.

(6) Between the tubules is a loose connective tissue containing numerous yellow epithelioid interstitial (situated in) cells and numerous lymphatics, blood vessels and nerves.

(7) The straight tubules, when within the mediastinum, unite, giving rise to a network of vessels called the *rete testis*.

(8) The rete testis leads into the *efferent ducts* (ducts leading out).

(9) The efferent ducts open into a single convoluted tube, the epididymis, situated at the posterior margin of the testis and attached to the mediastinum.

(10) The lower extremity of the epididymis runs into a thick-walled muscular tube, which is the vas deferens.

21. Spermatogenesis.—Spermatogenesis is the maturation, or production, of spermatozoa. By cell division, a spermatogonium divides into two parts, one of which continues to be a spermatogonium; the other passes into the second layer of the seminal epithelium, there increases in size and becomes a spermatocyte. Then, by a process of reduction, each spermatocyte divides and two secondary spermatocytes are formed; both of these also divide and four spermatids are produced, each of which develops into a mature spermatozoon.

A very important change, which occurs during the formation of the secondary spermatocyte, is that the original number of chromosomes is reduced to one-half. The chromosomes are the bearers of heredity; hence the great importance attached to this process of reduction. The number of chromosomes varies in the different species and may differ for the two sexes of a certain species; but it is constant for each sex of each species. Each chromosome has its homologous mate, and, preparatory to cell division, they arrange themselves in pairs (Fig. 3-A). The paired chromosomes

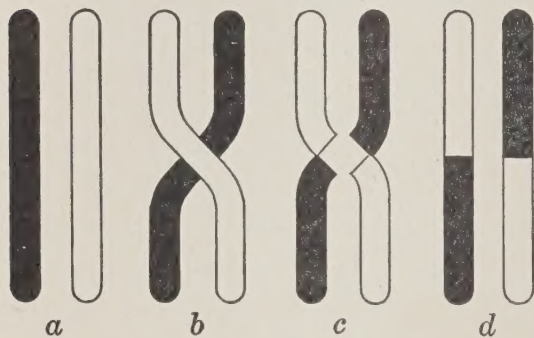


FIG. 3.—Interchange of chromatin between homologous chromosomes. (After Muller, from Babcock and Clausen's *Genetics in Relation to Agriculture*, McGraw-Hill Book Co., Inc., reprinted by permission.)

fuse along their entire length; this is followed by a twisting, cleavage, and separation, much as illustrated in Fig. 3b, c and d. The result is that, during the formation of the secondary spermatocytes, the chromosomes are reduced to one-half their original number; but during the division, an interchange of chromatin material between the homologous chromosomes has

taken place. Reduction occurs only during the formation of the secondary spermatocytes; during the other divisions of the ripening cells, the chromatin material divides into two parts, but the number of chromosomes in each resulting daughter cell is the same as in the parent, the process being similar to that of ordinary cell division (12).

The spermatozoon contains a centrosome, a nucleus with half the original number of chromosomes, and a very small amount of cytoplasm. It consists of a head, containing the nucleus; a body, containing the centrosome; and a tail, by which locomotion is made possible. Its appearance is

very much like that of a tadpole swimming about very actively by means of its tail (Fig. 4).

Sperm cells are discharged in large numbers although only one is needed for fertilization. It is estimated, in man, that one cubic centimeter of seminal fluid contains from sixty to seventy millions of cells.

22. The Other Male Generative Organs.²—The vas deferens is a duct furnishing passage for the semen from the epididymis to the ejaculatory ducts. Near its termination, the walls of the vas deferens contain a number of small tubular glands, which undoubtedly contribute to the seminal fluid.

The ejaculatory ducts, two in number, are formed by the narrowed extremities of the vesiculæ seminales and the vas deferens; they are located at the base of the prostate gland; and they terminate in the urethra by two orifices on either side of an opening which leads to the prostate gland. The function of the ejaculatory ducts is to convey to the urethra the fluid contained within the vas deferens and the seminal vesicle.

The vesiculæ seminales, two in number, serve as seminal receptacles as well as furnishing a contribution to the seminal fluid. The prostate gland also contributes to the seminal fluid. This is really a female degenerative organ and represents, in the male, the uterus and vagina of the female. In the horse, it is about four inches long and ascends into the folds of the peritoneum between the vas deferens; it opens to the urethra between the openings of the ejaculatory ducts. Cowper's glands, two in number, also contribute to the seminal fluid.

The secretions of the above-mentioned organs all empty

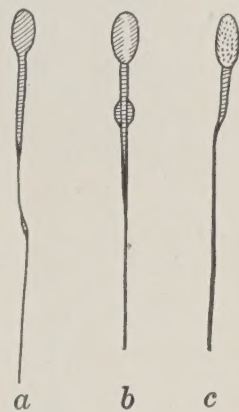


FIG. 4.—Spermatozoa.
(After Verworn, from
Schafer's *Essentials
of Histology*, reprint-
ed by permission.)
a, Ram; b and c, boar.

² Strangeway, *Veterinary Anatomy*, p. 350.

into the urethra where they mix with the seminal fluid of the testicles; undoubtedly, these secretions furnish the medium by which the spermatozoa are capable of carrying on life and activity. The spermatic fluid is alkaline in

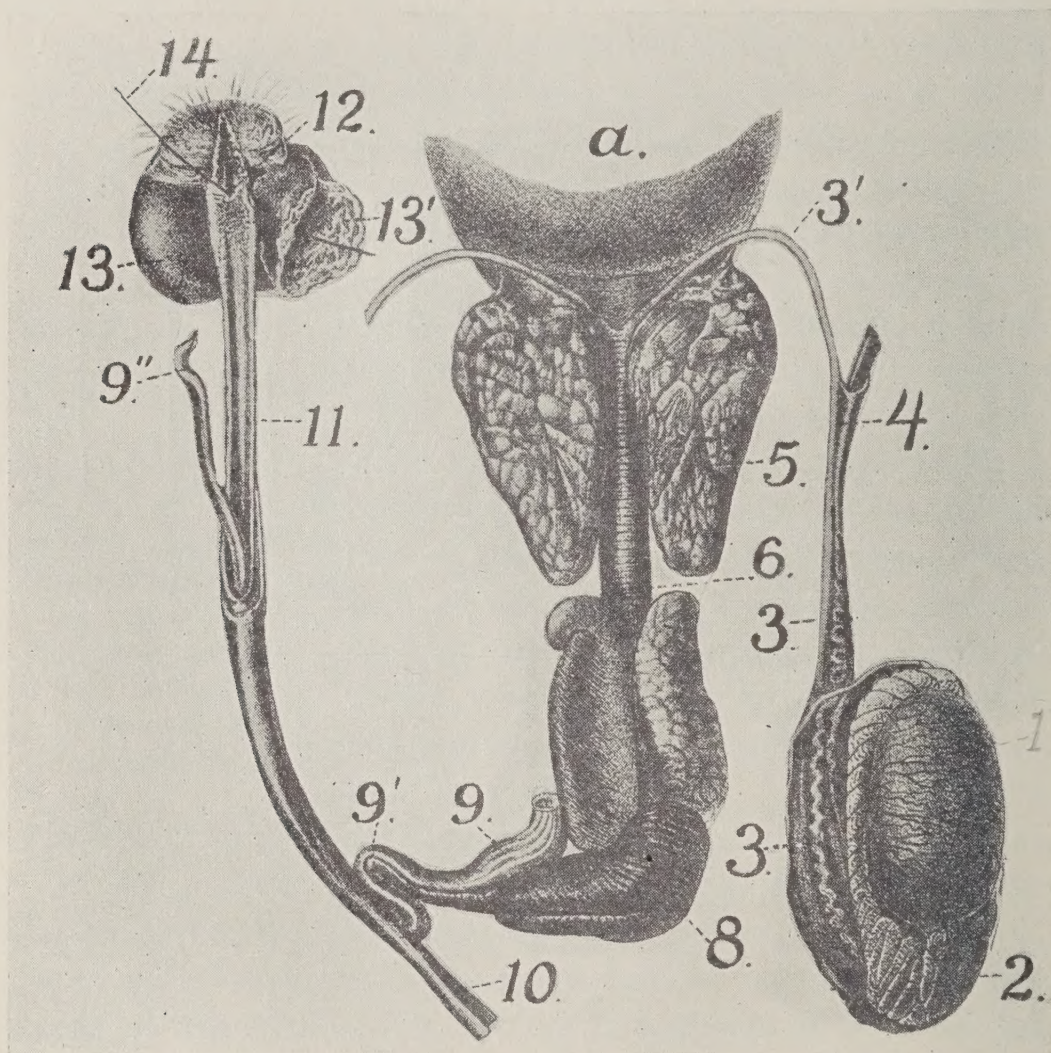


FIG. 5.—Male genital organs. (From Ellenberger-Leisering's *Atlas of Anatomy*, Alexander Eger, Pub., reprinted by permission.)

1, Testicle; 2, epididymis; 3, vas deferens; 4, artery; 5, vesiculæ seminales; 6, prostate; 7, Cowper's Gland; 8, muscle; 9, 9' and 9'', penis; 10, retractor penis muscle; 13, glans penis.

reaction, which is favorable to the activity of the sperm cells; it contains proteins, fats, and other substances from which the spermatozoa gain nutriment, for they are very lacking in cytoplasm.

The urethra leads from the bladder to the penis and through it to the glans penis. It is an excretory passage for the urine and semen. The penis, the male organ of copulation, is of two parts, namely, penis and glans penis, or end. It contains the greater part of the urethra and it is built of erectile tissue. The erectile tissue of the penis is so constructed as to allow gorging with blood, which causes the erection of that organ. The stimulation to erection is a nervous one, arising from the sacral portion of the brain.

23. Muscles of the Male Genital Organs.³—There are five muscles in the male genital organs: (1) The *cremaster* rises and assists in suspending the testicles. (2) The *accelerator urinae*, a pair, comprise the urethra and act as an auxiliary in the discharge of the urine and semen. (3) The *erector penis* maintains erection by blocking the return of the blood. (4) The *retractor penis* withdraws the organ after copulation. (5) *Wilson's muscle* embraces the Cowper's glands and adheres to the urethra; it comprises and aids in the discharge of the Cowper's gland and it contracts the membranous portions of the urethra.

24. Act of Ejaculation.—The impetus to ejaculation is a nervous one; it is accomplished by a contraction of the vesiculæ seminales, the prostate gland, and the vas deferens. The seminal fluid is thus forced into the urethra, out of which it is forced by contractions of the accelerator urinae and Wilson's muscles, which surround the urethra, and by contractions of the membranous portions of the urethra.

25. Female Genital Organs.—The genital organs of the female, beginning at the exterior, consist of the (1) vulva, (2) clitoris, (3) vagina, (4) os uteri, (5) uterus, (6) Fallopian tubes, and (7) the ovaries (Fig. 6).

26. The Vulva and Clitoris.—The vulva, the external genital organ of the female, in the mare and cow is from 6 to 10 inches long. The urethra opens into it, thus making

³ Strangeway, Veterinary Anatomy, p. 355.

the vulva an organ of urination as well as copulation. The clitoris, a small organ of erectile tissue comparable to the penis of the male, is located on the floor of the vulva.

27. The Vagina.—The vagina connects the vulva and uterus. It is an organ of copulation. In the mare, it is from 9 to 12 inches long in normal condition; its membrane is thrown into folds, which are transverse in the cow and

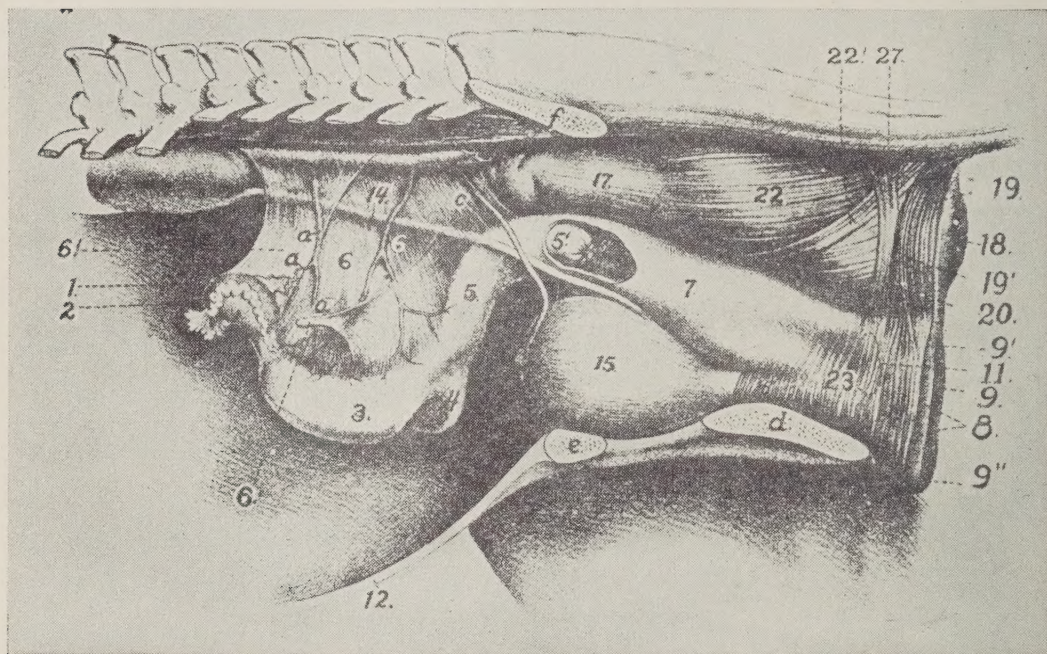


FIG. 6.—Genital organs of the mare. (From Ellenberger-Leisering's *Atlas of Anatomy*, Alexander Eger, Pub., reprinted by permission.)

1, Ovary; 2, Fallopian tube; 3, left horn of the uterus; 4, right horn of the uterus; 5, body of the uterus; 5' and 5'', os uteri; 6, broad ligament; 7, vagina; 8, vulva; 13, kidney; 15, bladder; 16, urethra; 17, rectum.

longitudinal in the mare. It is by means of these folds that this organ is capable of enlargement at the time of parturition.

28. Os Uteri.—The os uteri, the neck of the uterus, projects into the vagina. In reality, it is a part of the uterus, forming its external opening. In the cow, it is about $2\frac{1}{2}$ to 3 inches long; it has a very small opening, which explains the difficulty of artificial insemination in the cow. In the

mare, the opening is much larger. Two muscular rings circumscribe the os uteri; they dilate the os uteri at the time of oestrus and contract it after oestrus. The os uteri is completely closed only during pregnancy.

29. The Uterus.—The development of the healthy foetus takes place in the uterus. In the unbred mare, this body is oblong, varying from 5 to 8 inches in length and from $1\frac{1}{2}$ to 2 inches in width. Anteriorly, it divides into two horns, which in the mare are from 13 to 14 inches long and run downward and forward.

The walls of the uterus and horns are composed of three layers. The external layer is of serous membrane and merely encloses the organ. The middle one, a muscular tissue, has both longitudinal and circular fibers; the contractions of these muscular fibers are largely responsible for the expulsion of the foetus. The internal layer, composed of mucous membrane, secretes a heat fluid. In the cow, the mucous membrane is studded with processes called maternal cotyledons, each of which bears a resemblance to a half walnut. They come in contact with opposing surfaces of the foetal membrane and are the means by which the vascular circulation between parent and foetus takes place and the nutrition of the foetus is accomplished. There are no cotyledons in the mare, but the foetal membrane and uterine wall diffuse.

30. Fallopian Tubes.—The Fallopian tubes, two in number, lead from the horns of the uterus to the ovaries, or more properly speaking, they lead from the ovaries to the horns of the uterus. They are composed of a fibrous tissue with some muscle and have a white, ciliated epithelium lining, which has hair-like projections that whip the egg cells down the tube. The tube is about 10 to 12 inches long in the cow and mare.

31. Ovaries.—The ovaries are the most important female organs of reproduction; their function is to produce ripe ova. They are two in number and are located in the

sublumbar region, 20 to 22 inches from the exterior, in both the cow and mare.

The ovaries of the cow are about $1\frac{1}{2}$ inches long, $\frac{1}{2}$ to 1 inch in width, and almond-shaped; in the mare, they are kidney-shaped and weigh from 3 to 4 ounces; and in the sow, they are grape-like, she being a multiparous animal.

The ovary is enclosed in an outer covering or cortex, the germinal epithelium. This is composed of column-shaped cells containing round cells which develop into egg cells. The medulla, or center, is rich in bloodvessels, nerves, and lymphatics, with some connective tissue. It is in the cortex that the egg cells receive their start. These cells of the cortex, which contain the undeveloped egg cells, are sac-like and vary from $\frac{1}{100}$ to $\frac{1}{30}$ inch in size, depending upon the development of the egg cells, the more advanced of which are called Graafian follicles. As the egg develops, the follicle moves toward the center of the ovary where nourishment is more abundant. With more complete development, the follicle moves back to the cortex and breaks out as a rupture. A cross section of an ovary (Fig. 7) would exhibit a large number of Graafian follicles, representing various stages of development, scattered throughout its vascular system.

32. Oogenesis.—Oogenesis (maturation of the ovum) is concerned with the origin and development of a perfect ovum. The cells in the ovary, at birth, are imperfect; their number is a definite one and runs into several thousand. They complete their development, as required, some months or years after birth, depending upon the species of the animal. Only a few are matured at one time; and again, the species of animal determines whether they are matured at short intervals, as in humans, or at relatively long intervals, as typified in the bear, which in the wild state breeds only in the spring.

While the ovum is going deeper into the ovary and later coming to the surface, certain changes are going on within

the egg. The first step towards maturation is the process of cell division. Two cells of unequal size result; one is still the ovum, and the other the first *polar body*. Wodsedalek⁴ finds that, in the mare, the original number of somatic

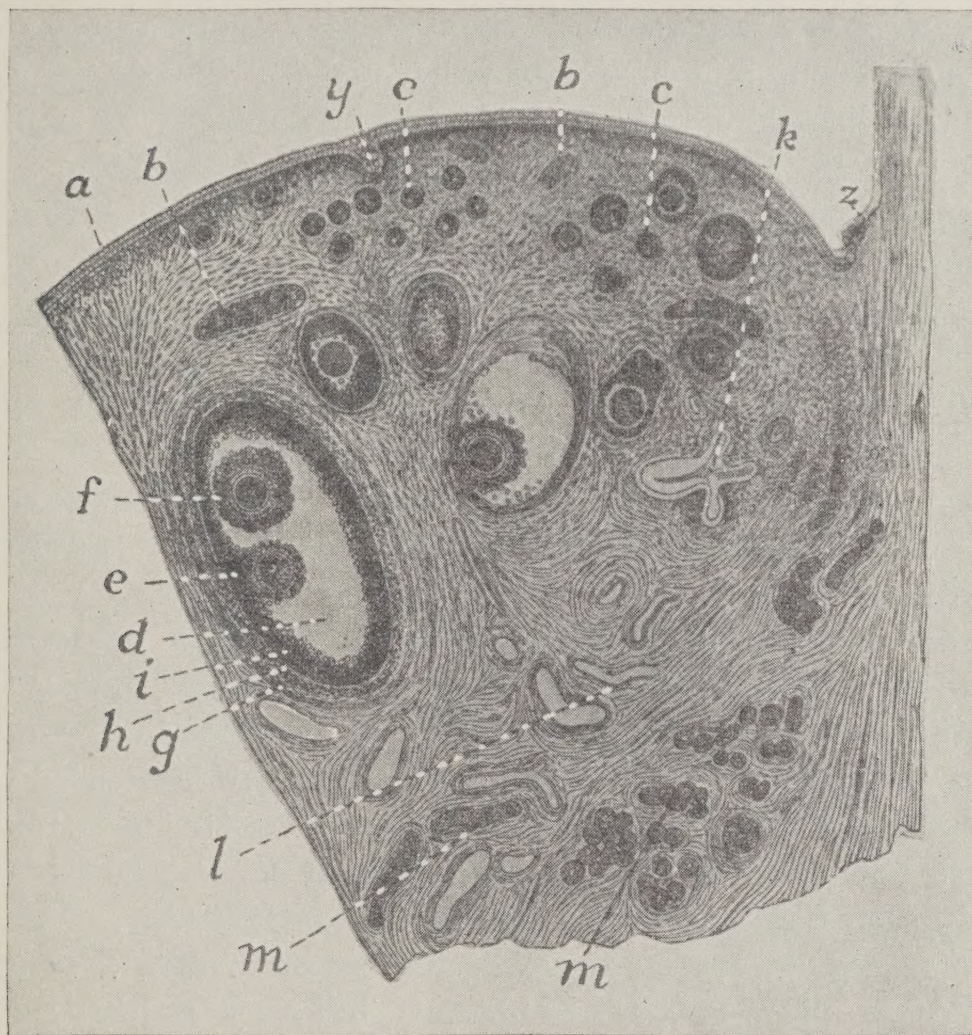


FIG. 7.—Section through ovary of adult dog. (From Waldeyer's *Physiology of Reproduction*, Wm. Engleman, Pub., reprinted by permission.)

a, Germinal epithelium; b, remains of egg-tubes; c, small follicles; d, advanced follicle; e, ovum; f, second ovum (rare occurrence); k, degenerate follicle; y, involuted germinal epithelium; z, transition from germinal to peritoneal epithelium.

chromosomes is 38. In the production of the first polar body, the original 38 chromosomes of the ovum are reduced to one-half this number, by a process similar to that which

⁴ Wodsedalek, J. C.; Biol. Bul. 27, 1914.

occurs in the formation of the secondary spermatocytes (21) (Fig. 3). The first polar body, containing one-half the original number of chromosomes (19 in the case of the mare) and but very little, if any, cytoplasm, is cut adrift; subsequently, it may divide again, forming two polar bodies. Following the production of the first polar body, the ovum divides again, and a second polar body is thrown off to become, like the first polar body and its daughter, an abortive cell. In the production of the second polar body, the chromosomes split longitudinally; thus, they double their number, one-half going to the polar body and one-half remaining in the ovum. One other important change that takes place is the loss of the centrosome by the ovum. Practically, no change or loss occurs in the cytoplasm. The ripe ovum, accordingly, has no centrosome and only half the original number of chromosomes; it is the function of the sperm cell to supply the missing parts.

33. Ovulation.—Ovulation is the discharge of the ovum from the ovary. According to Smith,⁵ in some animals, as in the rabbit and ferret, copulation is necessary to ovulation, the presence of the sperm cell within the uterus being necessary to ovulation. In farm animals, the ewe, sow, mare and cow, the act of copulation is not necessary to ovulation, which occurs with the period of oestrus. Ovulation, however, may occur without oestrus, and oestrus may take place without ovulation; but as a general rule, ovulation probably occurs during the latter part of the period of oestrus. The exact number of ova extruded during one sexual period is not definitely known; it is, undoubtedly, greatly in excess of the number impregnated. The mare is believed to shed only one at a time, but from ten to twenty during the year, and it is very likely that the ovaries function alternately. The cow and ass are also thought to usually shed only one ovum at each oestrus;

⁵ Smith, F. A., *Manual of Veterinary Physiology*, p. 702.

the ewe from one to four; the bitch, five to six; and the sow, ten to fifteen.

34. Graafian Follicle.—The part of the Graafian follicle not occupied by the egg is filled with a fluid which is absorbed, undoubtedly furnishing nutriment to the developing ovum, as the ovum ripens. At the time of ovulation, the remaining fluid is converted into a yellow body called corpus luteum. The corpus luteum is oval and firm and, in the mare and cow, about $\frac{3}{4}$ inch in diameter. It becomes an organ of internal secretion during pregnancy (76). If pregnancy does not occur, it is replaced by a white body called corpus albicans, which soon disappears.

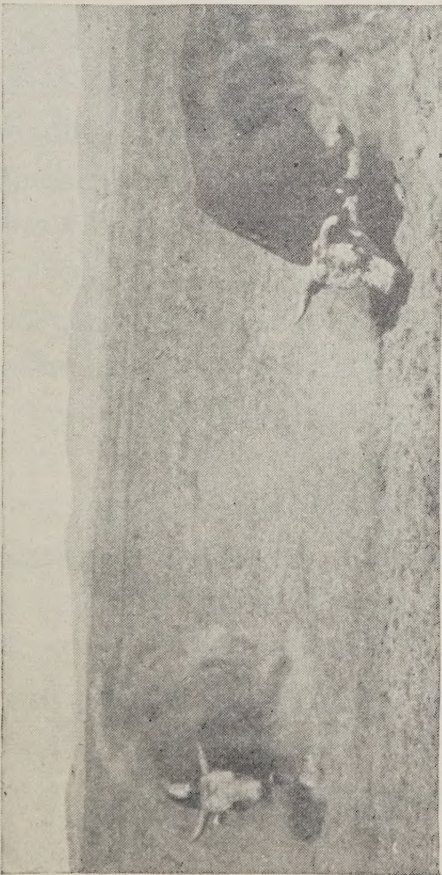
CHAPTER IV

THE OESTRUS CYCLE AND FERTILIZATION

35. Puberty.—The age of puberty marks the young animal's ability to reproduce. Previous to puberty, the nutritive system is very efficient; somatic growth is very rapid; and the generative organs are gradually developed until, at a certain period called "puberty," they become capable of generation. Marked changes in the individuals' physique take place at this time.

The first period of oestrus, or heat, and the first ovulation mark the arrival of puberty in the female. At this time, the female is generally high-strung or nervous, and the mammary glands noticeably increase in size. With the arrival of puberty in the male, there is a marked development of the forequarters, crest, and head; in the horned breeds of sheep and cattle, there is a thickening of the horns. The change is not only physical but temperamental as well; the animals become distinctly more nervous and often pugnacious, duels to death being not at all uncommon (Fig. 8).

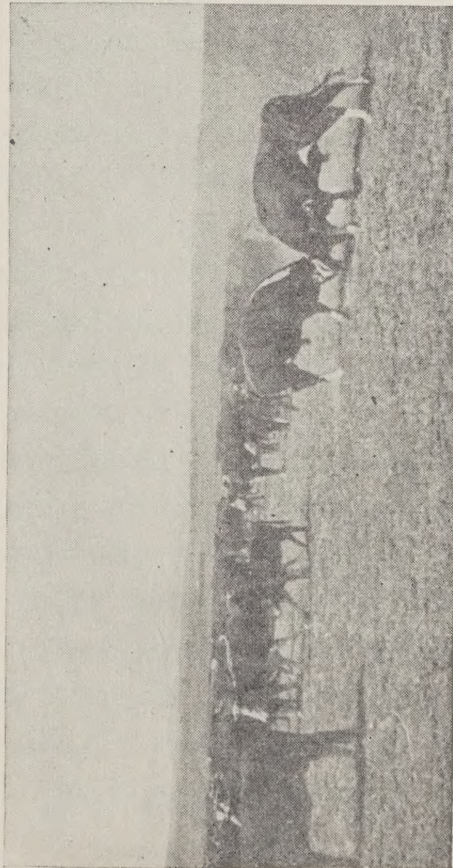
36. Age of Puberty.—The age of reaching puberty is governed by the following factors or influences: (1) species, (2) breed, (3) sex, (4) nutrition, and (5) individual. As a general rule, the representatives of the larger species and larger breeds within the species are slower in reaching puberty than the smaller ones. Without exact limitation, males are a little slower in reaching puberty than females. Animals reared under a favorable environment and state of nutrition will reach puberty at an earlier age than those



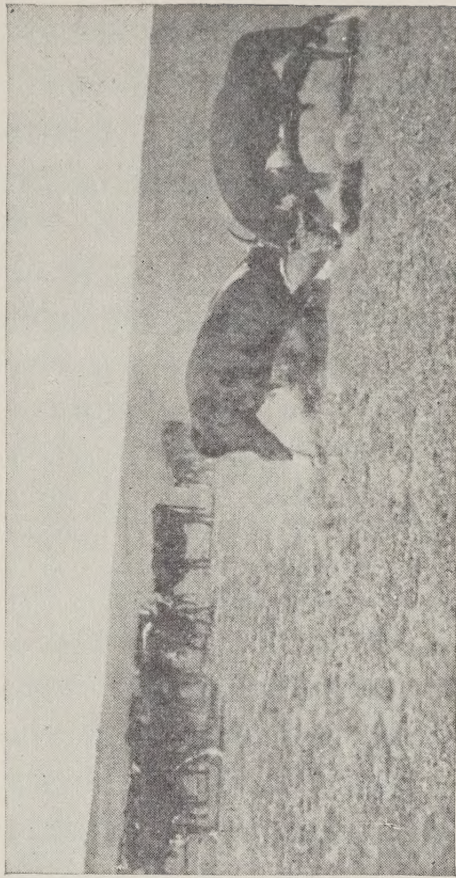
a, The Challenge.



b, The Defiance.



c, Round One.



d, Round Two.

FIG. 8.—Duel of range bulls. (*Courtesy, The Breeders' Gazette.*)

under less favorable care. Eckles ¹ has shown that well-fed heifers will, on the average, show oestrus three months earlier than those on a light ration. In addition, there are individual differences similar to other individual differences in characters.

The average age of reaching puberty, under ordinary farm conditions, is about as follows:

	Months
(1) Stallion.....	12-15
(2) Mare.....	12-18
(3) Heifer and bull.....	8-12
(4) Ewe and ram.....	5- 7
(5) Sow and boar.....	5- 6

37. The Breeding Season.—The breeding season is a certain period of the year when females show signs of mating. The season is influenced by heredity, environment, and nutrition. Some animals will breed at regular intervals throughout the whole year, but most animals show the most marked signs of breeding with the approach of warm weather in the spring. This is especially true in the case of the mare and cow. Ewes breed best in the fall, although Dorset Horns will breed at almost any time. Sows ordinarily breed in the fall, but they will mate at practically any season of the year if not pregnant or nursing.

Importers have long known that breeding animals, when first brought from Europe, often fail to breed, but after becoming acclimated, they breed regularly. Wild animals breed poorly or not at all in captivity.

An animal's state of nutrition has a distinct influence on the breeding season; far-seeing shepherds have long practiced flushing (increased feed) previous to mating. Experience has proven that, as the result of flushing, ewes come in heat more regularly and uniformly and produce a larger lamb crop.

¹ Eckles, C. H., Dairy Cattle and Milk Production, p. 209.

38. The Breeding Cycle.—During the breeding season, heat appears, for the most part, in quite regular cycles—every twenty-one days, in the case of the mare. This is the “dioestrous cycle,” and it is made up of four distinct phases, designated by Marshall:² (1) proestrus, (2) oestrus, (3) metoestrus and (4) dioestrus.

(1) Proestrus marks the animal's coming in heat. During this time, certain changes are taking place in the reproductive organs. The vulva, vagina, and uterus become congested with blood, which gives them a higher color. The mucous lining becomes more active in secretion, and blood often flows from the vagina.

(2) Oestrus, or heat, is the period when the female will receive the male, and it is generally accompanied by some or all of the following signs: (1) great restlessness, (2) decrease in milk flow, (3) cows ride other cows, (4) mammary glands of animals, not nursing young, increase in size, (5) frequent attempts at urination, (6) flow of heat mucous, which resembles the white of an egg, from the glands lining the vulva, vagina, and uterus, (8) flow of blood, and (9) a loss of appetite and weight.

The duration of oestrus is short in many animals, and especially so in the cow; therefore, if the herd bull is not running with the herd, little time should be lost in breeding after the first signs of heat. As a rule, the heat period in the cow lasts from twelve to twenty-four hours; in the ewe, three to four days; in the mare, four to five days; and in the sow, five to six days.

(3) Metoestrus is the period when the organs regain normal condition. If the female is bred and conception occurs, then oestrus is followed by gestation.

(4) Dioestrus, the period between metoestrus and proestrus, is the period of rest for the generative organs.

These four periods are known as the “dioestrous cycle,” which is usually sixteen days in the ewe and twenty-one in

² Marshall, Francis H. A., *Physiology of Reproduction*, p. 32.

the mare, cow, and sow. The cycle is repeated one or more times, until conception occurs or the breeding season is over. The number of dioestrous cycles occurring in one season is dependent upon the occurrence or non-occurrence of conception; if conception occurs, then under normal conditions there will be no recurrence of the dioestrous cycle until after parturition.

39. The Oestrous Cycle.—The final metoestrus period is followed by a prolonged non-breeding period, known as anoestrous, usually occurring, in the mare, from late summer until early spring. The occurrence of the dioestrous cycle marks the beginning of another breeding season. The complete cycle is known as the oestrous cycle. The number of oestrous cycles occurring in one year is largely dependent upon the species; the mare normally has only one, while the bitch has two.

The oestrous cycle and its various phases may be outlined as follows:

Oestrous cycle.

I. The breeding season—mating season.

1. Dioestrous cycle—cycle of heat.

(1) Proestrus—before heat.

(2) Oestrus—heat.

(3) Metoestrus—becoming normal.

(4) Dioestrus—short rest.

2. Repetition of the dioestrous cycle until the occurrence of conception or the end of the breeding season.

II. Anoestrous—long period of rest.

40. Fertilization.—Fertilization is the impregnation of the ovum by the sperm cell. Maturation of the sperm cells occurs previous to or at the time of copulation; and copulation occurs at oestrus. The spermatozoa are thus deposited within the vagina; but it has generally been observed,

by those gathering semen for artificial insemination, that considerable semen is injected through the os uteri and into the uterus at the time of copulation. The bulbous enlargement of the stallion's glans penis, at the time of copulation, points to the possibility of its grasping the os uteri, thus affording direct seminal injection; likewise, the pointed glans penis in the bull and ram suggests the possibility of direct injection of the seminal fluid.

Ovulation occurs at or near the time of copulation. The spermatozoon, after its deposition within the uterus, has to travel through the uterus, down the horn and up the Fallopian tube, there to meet and fertilize the ovum. The wriggling movement of the sperm cell, made possible by its tail, propels it towards the ovum. This movement of the spermatozoon is also undoubtedly aided by a chemical or an electrical attraction between the two cells; and the activity of the spermatozoon is further augmented by an alkaline medium, which under normal conditions is found within the uterus.

The ovum, on the other hand, is bulky and cumbersome, thus being incapable of locomotion; it is assisted down the Fallopian tube by the lashing of the hair-like lining (cilia) in the tube. Fertilization usually occurs within the Fallopian tubes. A single sperm cell penetrates the wall of the ovum, entering the cytoplasm; others may attempt to follow, but the surface of the egg at once becomes impervious to further attacks. Once lying inside the cytoplasm, the spermatozoon loses its tail, which is no longer required; the essential portions of that organism are the head and middle piece. The head, it will be remembered (21), contains the nucleus with one-half the original number of chromosomes, while the middle piece contains the centrosome. The ovum, by the process of reduction (32), has already lost one-half of its chromosomes and its centrosome, but has retained the cytoplasm; thus it is the sperm cell's function to supply the ovum's missing parts.

Two nuclei are now within the egg, one from the egg cell and the other from the sperm cell; they meet, fuse, and proceed with cell division under the direction of the centrosome. The fertilized cell has thus obtained one-half of the necessary chromosomes from each parent. Cell division goes forward by the longitudinal splitting of the chromosomes (Chapter II); thus it is that the one original cell is capable of giving a part of its substance to every developing cell that is later formed within the animal body.

Segmentation follows fertilization; it usually occurs within the Fallopian tube; and it is generally complete at the time it enters the uterus when, as a mulberry mass, it represents the foetus and attaches itself to the uterine walls.

41. Artificial Insemination.—The injection of semen into the female's genital organs (properly the uterus), without coition on the female's part, is known as artificial insemination; this is accomplished by the aid of instruments. Artificial insemination has the following advantages:

(1) It overcomes a constricted os uteri by the direct introduction of semen into the uterus.

(2) It overcomes an acid reaction of the vagina, which is unfavorable to the activity of the spermatozoa.

(3) Since several females may be impregnated by one copulation, it makes possible a wider use of an especially valuable male.

(4) It makes it possible to inseminate a mare without shipping her to the stallion.

42. Process of Artificial Insemination.—Artificial insemination has not been nearly so successful in cows as in mares, largely because of the small opening of the os uteri of the former. Semen is gathered, for artificial insemination, by means of a condom or a syringe. With the former, a sheath is put on the male previous to copulation. In the latter, the semen is collected by introducing the syringe into the vagina of a female immediately after service, placing the mouth of the instrument just above the depression, beneath

and in front of the cervix. The semen is then injected into other females by one of two methods: one is to insert the syringe directly into the vagina of another mare, injecting the seminal fluid into the uterus; the other is to take the gathered semen to a laboratory or warm room, there loading it into capsules, one of which is inserted into the uterus of each female to be bred. The latter method is more frequently practiced with the condom method of gathering semen; it allows for more wholesale breeding; but it has the disadvantage of retaining the semen outside the body walls for a longer time and also of not injecting as much semen into the uterus, thereby greatly reducing the chances of conception.

43. Spermatozoan Vitality under Artificial Conditions.—

The ability of the spermatozoa to withstand light, air, heat, and cold, and remain vital outside the animal body is of immense importance in artificial insemination. As the result of detailed studies covering these points in the horse, Anderson³ found that spermatozoa remain active longer at a temperature of 22° C. than at 38° C. (blood heat); but that in any case, 30 minutes is perhaps as long as they can be kept and used with safety. The reason for this is that the albuminous character of the semen makes it an ideal medium for bacterial growth, and the warmer temperature is more favorable to such growth than the lower one. On the other hand, exposing the semen to extreme cold (0° C.) rendered 50 per cent of the spermatozoa inactive within 30 minutes and 95 per cent inactive within 70 minutes. Extreme heat was equally disastrous, 25 per cent being rendered inactive after 32½ minutes' exposure to a heat of 46° C. and 95 per cent, after 44½ minutes.

Light, which has usually been regarded as very injurious to the life of the sperm cells, was found to have very little effect upon them. Direct sunlight appeared to have a stimulating affect upon the spermatozoa; but because of

³ Anderson, W. S., Kentucky Research Bul. 239.

this increased activity, the life of the sperm cell was shortened.

As the result of this investigation, it is apparent that the spermatozoa are sensitive to direct sunlight, and extremely sensitive to changes in temperature; and that for the best results in the practice of artificial insemination, the semen should be transferred as quickly as possible.

44. Spermatozoan Vitality within the Female's Genital System.—The conditions within the female genital organs are undoubtedly much more favorable to the existence of the sperm cells than artificial conditions. Investigations, however, indicate that their life, even within the female, is comparatively short. Lewis⁴ had twenty-five sows bred to a healthy boar and later killed, in order to determine the sperm cell's period of life within the uterus. In only three cases were the sperm cells alive after twenty hours, and in most cases they were all dead at the end of sixteen hours. Investigations by Anderson⁵ would indicate that the usual period of life for the sperm cells within the mare is even shorter.

45. Time of Ovulation.—Lewis⁶ found that the ovulation in the sow usually occurred thirty hours after the beginning of oestrus. Apparently, the sperm cell's life is relatively short even under favorable conditions, and ovulation usually occurs during the latter half of oestrus; therefore it would appear that the best time to breed the animals is during the latter half of oestrus, when heat is at its height.

⁴ Lewis, L. L., Oklahoma Bul. 96.

⁵ Anderson, W. S., Kentucky Research Bul. 239.

⁶ Lewis, L. L., *loc. cit.*

CHAPTER V

TWINS

46. Twin Births.—Twin births among horses and cows, as in humans, are not uncommon, although they are not the rule. Considerable interest has been aroused as to how twins originate. Are twin births of monozygotic (one fertilized ovum) origin or of dizygotic origin? It was at one time quite generally believed that twins were nearly always of monozygotic origin, but it is now quite generally conceded that they are, at least in most cases, of dizygotic origin.

If twins result from one fertilized egg, it would be necessary that a cleavage take place during the early stages of embryonic development, supposedly at the time of the zygote's first cell division. If such were the case, identical twins would result, for cell division is not only quantitative but qualitative as well; thus the twins would be identical in every respect. This, we know, by the observation of twins, to be exceedingly rare, if ever the case. Another reason for believing that twins are seldom, if ever, identical is that superfoetation (47) in horses and sheep, although rare, does occur.

Until quite recently, twins among cattle were almost always considered to be of monozygotic origin; but Lillie's work on the free-martin (48) plainly shows that they are almost exclusively of dizygotic origin.

47. Superfoetation.—The occurrence of oestrus, maturation, and ovulation during pregnancy is neither the normal nor the usual condition of affairs, yet they may occur; and

if copulation takes place, a second conception, which is known as superfoetation, may occur. Superfoetation means the later conception of an already pregnant female. This occurrence is not only interesting but it throws some light on the origin of twin births. In case the female is rebred to the same male or even to one of the same breed, it is very difficult to ascertain whether the twins have resulted from one or two acts of coition.

Mumford¹ reports several cases of superfoetation in the mule-breeding districts of Missouri, the mares having been bred first to a jack and later to a stallion, or vice versa, with twins, one a mule and the other a horse colt, as the result.

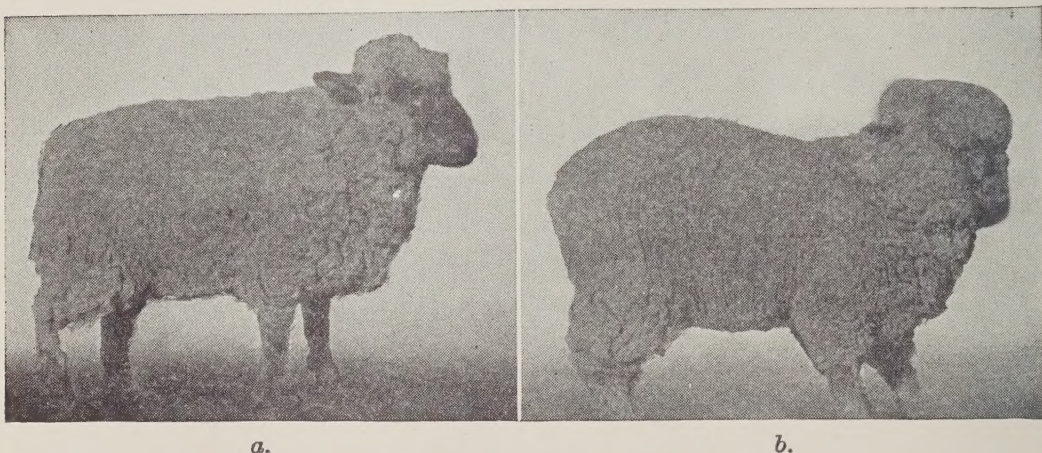


FIG. 9.—Twins, but only half-brother and sister. Out of a purebred Hampshire ewe, *a*, by a purebred Hampshire ram and *b*, by a purebred Rambouillet ram.

An instance of superfoetation in sheep occurred in the flock of the University of Saskatchewan. On November 24, 1921, the Rambouillet ram accidentally got into the Hampshire ewe pen; on December 1, 1921, the Hampshire ram was put with the flock; and on April 20, 1922, the Hampshire ewe No. 12 dropped twin lambs, one apparently a purebred Hampshire (Fig. 9-*a*) and the other plainly showing the markings of a Rambouillet-Hampshire cross (Fig.

¹ Mumford, F. B., *The Breeding of Animals*, p. 61-63.

9-b). The crossbred lamb weighed seven pounds at birth and presumably was dropped after a normal gestation period. The Hampshire was undoubtedly a premature birth; it weighed only five and one-half pounds and was saved only by very special care.

48. The Free-Martin.—The free-martin, a heifer co-twinning with a bull and generally sterile, has, for over one hundred years, attracted the attention of scientists, and until recently it has baffled them. John Hunter of England, over a century ago, did a great deal of work in dissecting the genital organs of the free-martin and attempting an explanation for its existence. His specimens were preserved and are still to be found in the museum of the Royal College of Surgeons.

While the free-martin is not of any great economic importance in itself, it is of great importance in the light it throws on other related subjects.

49. Description.—In the past, the free-martin has been considered by many as a hermaphrodite. A hermaphrodite, properly speaking, should contain a mixture of all the parts of the genital organs of both sexes. A description of one of John Hunter's specimens, given by him and re-presented by D. Berry Hart,² comes nearer to filling that requirement than any other that has come to the writer's attention. It is as follows: "This animal was seven years old; went with the cows and bull; never showed any desire for either. The external parts were rather smaller than in the cow; the vagina was contracted above the urethral opening, becoming continuous with a small canal; uterus with two horns, ovaria and testicles; vasa deferentia to the testicles; the left one did not come near the testicle, the right one only came near to it but did not terminate in the epididymis. They were both pervious to and opened into the vagina near the urethra. Vesiculæ seminales were present, smaller than in

² Hart, D. Berry, Reproductive Organs in the Free-martin. Proc. Royal Soc. of Edinburgh, Vol. 30.

the bull; the ducts opened along with the vasa deferentia."

50. Assuming the Free-Martin to be an Imperfect Male.—D. Berry Hart did a great deal of work in recent years on the free-martin. He came to the conclusion that the free-martin was properly a male calf co-twinning with a perfect male calf. He explained its existence upon the ground that the twins were identical twins resulting from the cleavage or cell division of one fertilized zygote, with the result that the somatic determinants divided equally and the genital determinants divided unequally, one division being potent and developing into a potent bull, the other division being non-potent and developing into a free-martin. D. Berry Hart, as well as the early investigators, confined his studies to specimens from birth on.

51. Number of Chorions in Twin Births.—It remained for Frank R. Lillie,³ of the Zoological Laboratory, University of Chicago, to clear up this long-standing mystery.

He approached the subject by examining unborn twins, expecting to satisfy himself as to whether bovine twins were of monozygotic or dizygotic origin, by their presence in single or double chorions. To his surprise, he found, with but two exceptions out of the fifty-five cases of bovine twins examined, that they were all monochorial, and furthermore, that some of these were perfect male twins and others perfect female twins. After he had been working for some time, it became clear to him that the presence of the twins in one chorion was no proof that they were monozygotic, because, as will be brought out later, it is possible for two chorions to fuse into one.

52. Number of Ova Concerned in Twin Pregnancy.—He next directed his attention to the number of ova concerned in twin pregnancy, this to be ascertained by the number of corpora lutea present. The object of determin-

³ Lillie, Frank R., Action of Sex Hormones in Foetal Life, Jour. of Exp. Zoo, 23.

ing the number of corpora lutea was that, if two corpora lutea were found for all free-martin twins, the dizygotic origin would be proven, provided the rule holds for cattle. As he had at first expected to decide whether the twins were of monozygotic or dizygotic origin by the presence of single or double chorions, the ovaries of the first specimens were not examined. Of the 22 cases in which both ovaries were present, there was a corpus luteum in each ovary. Seven of these were ♂♂ (male twins); 4 ♀♀ (female twins); 10 ♂♂₊; and 1 too young for sex diagnosis. On the other 33 cases, the data were incomplete, as both the ovaries had not been saved. The question then was, "Is only one corpus luteum, or two, present in cases of single births?" Lillie, therefore, next directed his attention to determining the number of corpora lutea present in the case of single births. Eighty-one uteri, each containing a single calf, were examined. In 45 of these, both ovaries were present and in each case only a single corpus luteum was found; in 36 cases, only one ovary was present, 18 of these containing a single corpus luteum and the other 18 lacking a corpus luteum.

The conclusion drawn from the embryological evidence is that heterosexual bovine twins are usually dizygotic. This is also supported by the lack of close resemblance between the bull and heifer of such pairs. Monozygotic twins would necessarily be homologous twins. Lillie presents a very striking instance to prove that this is not the case. The twins were purebred Holstein-Friesians; the free-martin was spotted, being about half black and half white, while the male was entirely black except his forehead and legs.

53. Embryological Study.—Normally, the ovum is fertilized in the Fallopian tube, then passes into the horn of the uterus, and, when the embryo is about 10 mm. in length, it is well in the body of the uterus. In the case of twin pregnancies in cattle, the two vesicles, starting in opposite horns of the uterus, will meet in the body of the uterus

before the 11 mm. stage. When the vesicles are about 15 mm. long, the two chorions are overlapping and ready for fusion. From this time on, fusion of the chorions and vascular anastomosis begins to take place; and there is a free exchange of blood between the two after the 15 mm. stage (Fig. 10). When the 75–80 mm. stage is reached, fusion of the chorions is perfect.

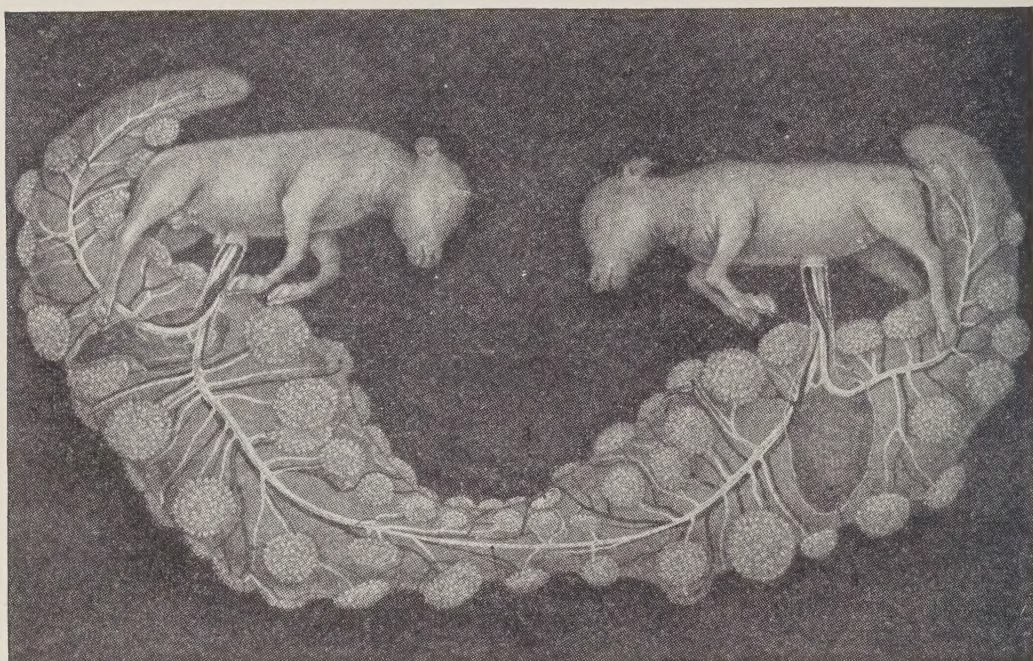


FIG. 10.—Twin chorionic vesicle of cow. (After Lillie, courtesy *The Journal of Experimental Zoology*.)

1, Arterial through trunk; 2, cotyledon with venous connection with both sides; 3, amniotic sacs opened; 4, clitoris of free-martin.

54. The Hormone Theory.—The above facts give rise to Lillie's hormone theory of the free-martin which, in brief, is that the male calf casts hormones in its blood, these flow to the female calf and stimulate the recessive characters present in the female embryo, thus causing the sterile free-martin. In all the cases of two-sexed twins, examined by Lillie, where vascular anastomosis had taken place, the female was a free-martin; and where vascular anastomosis had not taken place, the female was sexually normal. He also found cases of male twins, and also female twins, where

vascular anastomosis had taken place, and they were in all cases perfectly normal. This proves that the free-martin is a female.

Lamb twins are also found in a single chorion and the question naturally arises: "Why do we not have lamb free-martins?" But, in the case of lamb twins, vascular anastomosis does not take place.

Another question that naturally arises is: "Why is the female always affected?" The answer is that the male's genital organs develop at an earlier age than the female's organs; therefore the male hormones stimulate the recessive male characters in the female before the dominant female characters are stimulated by her own hormones. Whitehead and Allen have considerable data on pigs, reviewed by Lillie, showing that in the male the genital organs develop earlier than in the female. According to their work, interstitial cells are present in both the testis and ovary of the pig at the 2.5 C.M. stage; but while they are very numerous in the testis at this stage, they are very rare in the ovary. Assuming that a similar condition prevails in the bovine foetus, the hormone theory is a very plausible explanation for the occurrence of the free-martin.

CHAPTER VI

SEX

55. Sex Determination.—The subject of sex determination is of great interest and is extensively discussed among farmers and stockmen. Sex has an important bearing on the economic value of much of our livestock (steers, barrows, and geldings being in favor on the markets), and for this reason, sex control is considered of great importance by many stockmen. Many suppositions regarding sex control have, from time to time, been put forth; a few of these, which have at some time attracted considerable attention and are still believed in by many, are discussed in the succeeding paragraphs.

56. Age and Vigor of Parents.—One popular belief is that a larger percentage of the offspring will be of the same sex as the older parent. Another and a closely allied belief is that the larger percentage of the offspring will be of the same sex as the more vigorous parent. In other words, this belief is that if an immature male were used, he would get more females than males; as he attained maturity and his vigor increased, the proportion of males would increase; with increased age and a decline in his vigor, there would be a corresponding decline in the percentage of male offspring. This supposition is based upon the presumption that the male secretes male determiners only, and the female, female determiners only; and that the sex of the resulting offspring is determined by the strength and vigor of the respective sex cells.

Numerous data have been gathered regarding this

assumption; the results, as would be expected in the light of present scientific knowledge, are conflicting and therefore negative.

57. Influence of Nutrition.—The belief that the mother's state of nutrition, during the gestation period, will determine or at least influence sex in the offspring, is a very old conjecture. The theory, if such it may be called, is that if the mother is well nourished, the offspring are more likely to be females, and if she is undernourished, they are more likely to be males.

Here again, numerous data have been gathered, and again, as might be expected, the results are conflicting. If this assumption were correct, one might expect *show* females, which are generally in a high condition, to drop female offspring almost exclusively; and, on the other hand, one might expect *range* females, during the frequent years of short range, to drop an unusually large proportion of male offspring. Practice has proven that this is not the case.

58. Male and Female Ovaries.—It is also held that the right ovary secretes only male-producing ova, and the left only female-producing ova; that the ovaries function alternately and thus sex is dependent upon the one from which ovulation occurred. A similar claim has been advanced regarding the testicles, but neither theory has stood the test of testicle or ovary removal.

59. Time of Mating.—Still another widespread belief is that if fertilization occurs early in oestrus, a greater proportion of the offspring will be females, and *vice versa*. In other words, it is held that sex depends on the stage of development of the ovum at the time of fertilization. If this should be the case, then, under ordinary farm and range practice, where the males ordinarily run with the females and mating occurs early in oestrus, it might be expected that a majority of the offspring would be females; but the sexes, over large numbers, remain about equal. On

the other hand, over large numbers, it cannot positively be stated that the time of mating would have no influence on sex determination, as will be discussed later (61).

60. Accessory Chromosome Theory.—During recent years, the belief has been growing that sex is controlled by internal factors rather than external. In studies of *Drosophila*, it has been found that the female yields only one kind of sex cell while the male yields two kinds, and that sex determination depends upon which one of these male cells fertilizes the egg. The somatic cell of *Drosophila* contains eight chromosomes; by the process of reduction, during maturation, they are reduced to four, which in the female consist of two large, curved autosomes (chromosomes other than sex), one small autosome, and one club-shaped chromosome called the X-chromosome—a sex determiner. The male matures two kinds of germ cells: one like that of the female, and the other different only in that the sex chromosome, in place of being club-shaped, has a hook; this is called the Y-chromosome—male determiner. Since the somatic cell contains one X- and one Y-chromosome, these male and female determining germ cells are produced in equal numbers; hence sex determination depends on the random mating of the germ cells. This would explain the numerical equality of the sexes, when large numbers are considered.

61. Sex Determination in Higher Animals.—Apparently, sex determination among higher animals is also of the XY type, although possibly somewhat modified from that of *Drosophila*. Wodsdalek¹ finds that the somatic cell of the mare contains 38 chromosomes, while that of the stallion contains only 36. In the process of reduction, the mare produces germ cells containing 19 chromosomes; the stallion, on the other hand, produces two kinds of germ cells, one containing 17 chromosomes and the other 19; thus, if the ovum is fertilized by a spermatozoon containing

¹ Wodsdalek, J. E., Biol. Bul. 27 and 25.

only 17 chromosomes, a male results, and if it is fertilized by one containing 19 chromosomes, a female results.

In swine, the situation is much the same: the female somatic cell contains 20 chromosomes, and the male 18; supposedly, the female produces only one kind of gamete (sex cell) containing 10 chromosomes, while the male produces two kinds of sex cells, one containing 10 and the other 8 chromosomes; hence, sex determination is again dependent upon the random mating of the gametes. Wodsdalek found also that two different-sized sperm cells were produced in approximately equal numbers. It is not too much to infer that the larger contains the accessory chromosomes and is thus the female determiner. If it should later be proven that one or the other was more active or more resistant to time, it can be seen how the time of breeding might, over large numbers, affect sex determination (59).

62. Sex Determination beyond Control.—Much has been revealed, during the past few years, about sex determination, and much is yet to be revealed; however, enough is known to make it evident that sex determination is internal and beyond the control of man. Despite the fact that it might be desirable at times to have a total crop of males and at other times to have a total crop of females, it is well that sex control is beyond human regulation, for it would undoubtedly be abused.

63. Secondary Sex Characters.—Among the higher animals, sex is not recognized by the sex organs only. Certain characters, as the bull's burly head, the boar's tusks, and the stallion's crest, point them out as male animals. These are called secondary sex characters.

64. Cause of Secondary Sex Characters.—Secondary sex characters are undoubtedly due to a hormone stimulation from the ovaries or the testicles, as the case may be. Everyone is familiar with the differences in development of the castrated and uncastrated male calf, pig, or lamb, and with the change in a boy's voice on reaching the age of puberty.

On reaching puberty, the secondary sex characters of the male develop very rapidly (35).

65. Effect of Castration and Ovariectomy.—Incomplete development of the horns accompanies castration of a horned ram lamb; likewise in the steer, the horns, head and forequarters are not so fully developed as in the bull. Castration in mammals tends to throw the somatic development toward the female side. Ovariectomy, on the other hand, appears to effect little outward change in the mammals. Darwin, who traveled extensively during his studies, reported, however, that among certain barbarous tribes it was customary to ovariectomise some of the girls while still young, and that the girls so treated developed, to a very considerable extent, the outward characters of the male.

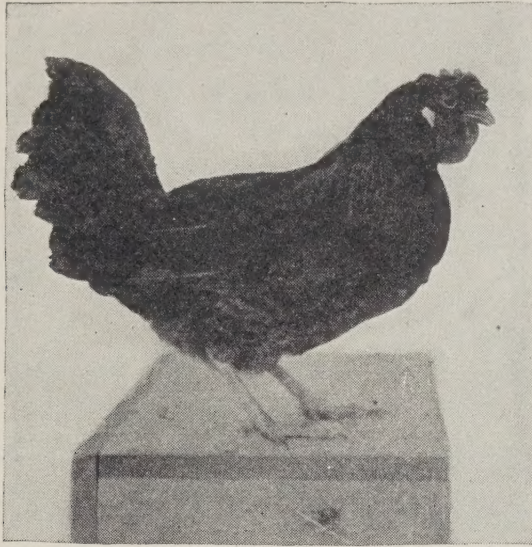
Among birds, the reverse seems to be the case, castration causing but little change and ovariectomy throwing the sexual development on the male side. The male and female in Rouen ducks have plumage of very different colors, the male's being blue-gray and the female's brown. Goodale² removed the ovaries of a six-weeks old bird; at twelve weeks of age, it showed the male characters very strongly; later in the year, after molting, it had the same appearance as the male. Although the bird molted several times afterwards, there was no apparent tendency to adopt female characters. Castration, on the other hand, effected but little outward change in the drake.

66. Transplanting Sex Glands.—That the sex organs furnish the necessary stimulus—undoubtedly a hormone—to the development of the secondary sex characters has been proven quite conclusively by the experimental transplanting of sex glands from one sex to the other. Steinach³ castrated male guinea-pigs and rats and transplanted ovaries in them. The animals became strongly feminized, and the mammary glands, in both cases, became much enlarged.

² Goodale, H. D., *Jour. of Exp. Zool.*, Vol. 10.

³ Steinach, E., *Arch. Gesell. Physiol.*, 144.

The rats took on the texture of hair, size of skeleton, and sexual behavior of females. In general, the whole trend of development was thrown toward the female side.



a.



b.



c.

FIG. 11.—A feminized cockerel. Photographs made at varying distances.
(*Courtesy H. D. Goodale.*)

a, Taken December 14, 1914; b, September 17, 1914; c, July 30, 1915.

Goodale⁴ castrated a twenty-four-day-old brown Leghorn cockerel, at the same time placing pieces of fresh

⁴ Goodale, H. D., *Genetics*, Vol. 3, May, 1918, and *The Journal of Experimental Zoology*, No. 3, Vol. 20.

ovaries, from two brood sisters, under the cockerel's skin. The bird developed, in every external character, like a female, and even expert poultrymen were unable to distinguish him as a male bird (Fig. 11).

These experiments, while interesting in themselves, show quite conclusively, as did Lillie's work on the free-martin (54), that the genital organs secrete hormones, which stimulate the growth of other characters, which on development are called secondary sex characters. They show also that there are certain characters apparently lying dormant in the ordinary male and female; for when the necessary stimulus is supplied by the opposite sex glands, secondary sex characters of the opposite sex are developed.

67. Recessive Sex Characters.—From the above, it is quite evident that there are certain characters lying dormant in the male and others lying dormant in the female. Lillie's work on the free-martin (54) also lends support to this assertion. And lastly, the anatomical arrangement of the male and female, among higher organisms, shows that each contains a certain amount of degenerate sex tissue and sex organs belonging to the opposite sex, as the prostate vesicle in the male (22), which represents a degenerate uterus and vagina, while the clitoris in the female (26) represents a degenerate penis.

CHAPTER VII

GESTATION AND PARTURITION

68. Gestation.—Gestation, pregnancy, or gravidity is the period between conception and parturition.

69. Indications of Gestation.—There are several signs and tests that indicate cases of pregnancy. The cessation of oestrus, before the close of the breeding season, in an individual in which oestrus has been regular, is a good indication of conception. A seal known as the “uterine seal,” or “seal of pregnancy,” closes the opening of the os uteri to the vagina. In many cases, this is capable of palpation by inserting the arm into the vagina, the “uterine seal” being recognized by its sticky character. Still another method of recognizing pregnancy during its early stages is by palpation of the ovaries through the rectum; the presence of a corpus luteum within the ovary can thus be determined. The last two methods, however, are not to be practiced by the layman but should be left to those experienced in the examination of these organs, for abortion may be caused by careless or rough treatment of this kind.

Other and later indications of pregnancy are that the female often becomes more languid and frequently takes on flesh readily; females that were normally sweet-tempered often become cross and easily irritated, while those having rather surly tempers frequently evince more docility. During the latter half of gestation, there is a marked development of the mammary organs; this usually occurs earlier during the female's first period of pregnancy and later in older breeding females. During the latter half of gestation,

the presence of the foetus can usually be quite easily distinguished by abdominal enlargement, especially on the left side, and if the cow or mare be given a drink of cold water, foetal kicks are not unusual.

70. Foetal Membranes.¹—Enveloping the mammalian embryo is the amnion, a sac containing a fluid in which the foetus lives. This amniotic fluid is alkaline in reaction and contains proteins, sugar, lactic acid, keratin, salts, mucin, and urea. Early in the gestation period, it is yellow in color, later on turning reddish, undoubtedly because of meconium discoloration. This fluid is, without doubt, derived by a transudation from both foetus and dam; and its function is to protect both mother and foetus by serving as a bed for the latter.

The allantois or middle membrane completely encloses the amnion in the mare, while in ruminants it only partially encloses it. This membrane also contains a fluid, which is derived from the foetal urine and contains urea, albumin, sugar, lactic acid, and some salts. It is the organ of respiration and, to a certain extent, nutrition.

The chorion, or outer covering, envelops both previous coverings. It forms the vascular connection between dam and foetus; by means of the umbilical cord, it connects with the foetus; and by means of certain villi on its outer surface, which project into the mucous membrane of the uterus, it communicates with the dam. Vascular anastomosis of the chorion and uterus does not occur; but the villi of the chorion, which project into the uterine sinuses, are bathed in the mother's blood; thus the foetal blood is furnished with oxygen and nutrients and likewise relieved of carbon dioxide.

The umbilical cord, which is attached to the foetal body wall and connects the foetus with the placenta, is composed of several structures, which form the umbilical vascular system. These structures connect the amnion to the body

¹ Smith, F., *Manual of Veterinary Physiology*, p. 711-713.

wall at the umbilicus and the allantois with the urachus (Fig. 12).

71. Embryo and Foetal Nutrition.—With fertilization, the sperm cell supplies half the necessary chromosomes and the missing centrosome, while the ovum furnishes the other half of the chromosomes and the cytoplasm. The cyto-

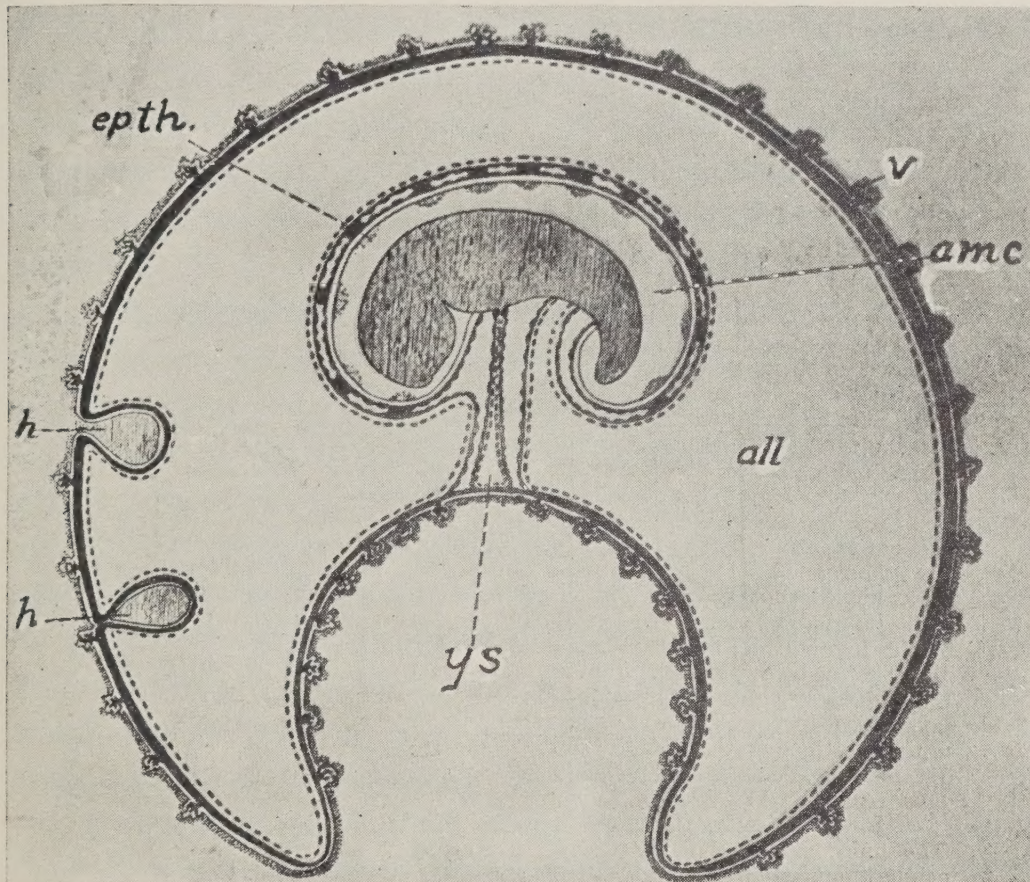


FIG. 12.—Foetal membranes of the horse. (After Bonnet, from Jenkinson's *Vertebrate Embryology*, Oxford Press, reprinted by permission.)

v., Villus; *ep. th.*, epithelial thickenings of the amnion; *h*, hippomane; *am. c.*, amniotic cavity; *all*, allantois; *y. s.*, yolk-sac.

plasm furnishes enough food to last until segmentation is completed. At this time, a spere called the yolk sac is formed, in which there is a yolk-like substance that is really uterine milk derived from subterranean cells of the uterine wall. The embryo of the mare is completely nourished by the yolk sac until the seventh week.

With the exhaustion of the yolk sac, the foetus is nourished by being brought indirectly into communication with the dam's vascular system. In some animals the communication is apparently more direct than in others, but in general, it is accomplished by means of the umbilical vascular system, which connects the foetal vascular system with that of the chorion, which in turn is in direct or indirect (as the case may be) communication with the vascular system of the dam.²

72. Period of Gestation.—The period of gestation has a more or less definite relation to the size of the species, as in the elephant the period is from 20 to 23 months, while in the mouse it is about 21 days.

The average period of gestation for farm animals is as follows:

	Months	Days
Ass.....	11½ to 12	345 to 375
Mare.....	11 to 11½	330 to 340
Cow.....	9	270 to 295
Sheep or goat.....	5	143 to 150
Sow.....	4	115 to 120
Bitch.....	2	58 to 64
Cat.....	2	60 to 64

73. Variation in Period of Gestation.—The period of gestation is subject to considerable variation. Some general causes are quite evident, but many cases of variation are very difficult of explanation.

It is very possible that heavy and prolonged lactation may inhibit foetal nutrition; this may retard foetal development and it in turn may prolong gestation.

It is quite evident that, in a general way, the early-maturing species have a shorter period of gestation than

² Marshall, Francis H., The Physiology of Reproduction, Chap. X.

late-maturing ones. Darwin's work³ would indicate that the earlier-maturing breeds within the species likewise have a shorter period of gestation. Darwin's observations cover the grading-up of Merino sheep with the earlier-maturing Southdown. He found the period of gestation to average 150.3 days, in purebred Merinoes; 144.2 days, in purebred Southdowns; 146.3 days, in Southdown-Merino crosses; 145.5 days, in the three-quarter Southdowns; and 144.2 days, in the seven-eighths Southdowns.

There is a popular belief that males are carried longer than females; many data have been gathered regarding this point, but the results are too conflicting to support any such assertion.

Another popular belief is that if the dam is well nourished during pregnancy the gestation period will be shorter. If this is the case, it is undoubtedly due to the more rapid development of the foetus, but here again there is no experimental support for the belief.

74. Incubation.—Incubation in fowls corresponds to gestation in mammals. The period of incubation, like that of gestation, is subject to variations dependent upon conditions, such as weather, breed, humidity, and the setter's mindfulness, e.g., eggs will hatch a day or two earlier in warm weather; eggs from the small breeds will hatch two to three days earlier; likewise, increased humidity and a close and regular setter will shorten the period of incubation.

On the average, the period of incubation in domestic fowl is as follows:

	Days
Canary birds.....	14
Pigeons.....	18
Chickens.....	21
Guinea hens.....	25
Ducks.....	28
Turkeys.....	28
Pea hens.....	29
Geese.....	30

³ Darwin, Charles, *Animals and Plants under Domestication*, Vol. I, p. 123.

75. Indications of Parturition.—As indicated above, the period of gestation is variable; therefore the signs of approaching parturition should be carefully watched. The experienced stockman usually has little difficulty in recognizing the approach of parturition, which is indicated by certain well-recognized signs.

One of the most conspicuous signs of approaching parturition is the distended mammary development; the udder fills first, then the teats, and a milk flow is not uncommon. Ordinarily, a wax is present on the teat tips—most manifest in mares—which prevents the loss of milk. Generally, parturition will occur within 48 hours after the first appearance of wax, but not necessarily. The presence of wax is a positive sign of approaching parturition; but frequently young are born before the dam's mammary organs are functioning properly, and, in rare cases, certain stimulations will cause milk flow without pregnancy.

Another almost unfailing sign of parturition is an increased growth of the vulva; it not only spreads, but the lips become swollen as well. Frequently a mucus discharge, which is often stained with blood, occurs.

A falling away at the hips is a symptom of approaching parturition. This is generally more conspicuous in the mare than in other farm animals, but it may be noted in all. It is due to a relaxation of the muscles and ligaments at the hips, thus allowing more expansion at the time of parturition. Hence, it is indicated by the depressions on either side of the croup.

Most animals become more or less nervous at this time, and just previous to parturition, they will, if possible, isolate themselves from both man and beast; the cow will hunt the brush; the sow, the straw stack, etc. Sows generally make a nest just previous to farrowing, and if but little straw or hay is available they are quite conspicuous by their gathering together odd bits of hay and straw into a neat nest.

76. Inciting Cause of Parturition.—Parturition is the expulsion of the fully developed foetus at the end of a normal gestation period. Abortion is the expulsion of a premature foetus. Various causes have been advanced as to the inciting cause of parturition. Beard⁴ suggests that the oestrus cycle and parturition have a very intimate relationship. It is well known that abortion usually occurs at the periodical time when heat would be present. Spiegelberg⁵ suggests that the foetus secretes a hormone which, acting upon the nerve centers, stimulates the uterine nerve centers of the spinal cord. It is held by others that the corpus luteum secretes a hormone which prevents the expulsion of the foetus, and that the cessation of this secretion causes parturition. This theory gains evidence from the fact that if the corpus luteum be squeezed out of the ovary, during the early period of gestation (which is quite possible by palpation of the ovary through the rectum) abortion follows. But, according to Smith,⁶ the corpus luteum does not function during the latter half of pregnancy, and, if such is the case, it disproves the above-mentioned contention that a cessation of hormone secretion by the corpus luteum is responsible for parturition.

Still another contention is that the decaying placenta secretes hormones, which furnish the real stimulus, as it is well known that the death of the foetus usually results in its expulsion.⁷ Several other possible causes have been suggested; but for the most part, they are based on speculation rather than experimental evidence. Williams⁸ suggests that the onset of labor may be due to a combination of several causes. It is very possible that a hormone is the

⁴ Beard, *The Span of Gestation and the Cause of Birth*, Jena, 1897.

⁵ Spiegelberg, *Die Dauer der Geburt, Lehrbuch der Geburtshilfe*, Vol II, 1891.

⁶ Smith, *Manual of Veterinary Physiology*, p. 698.

⁷ Simpson, *loc. cit.*

⁸ Williams, *loc. cit.*

inciting cause of parturition, but just what it is, or what organ secretes it, is unknown.

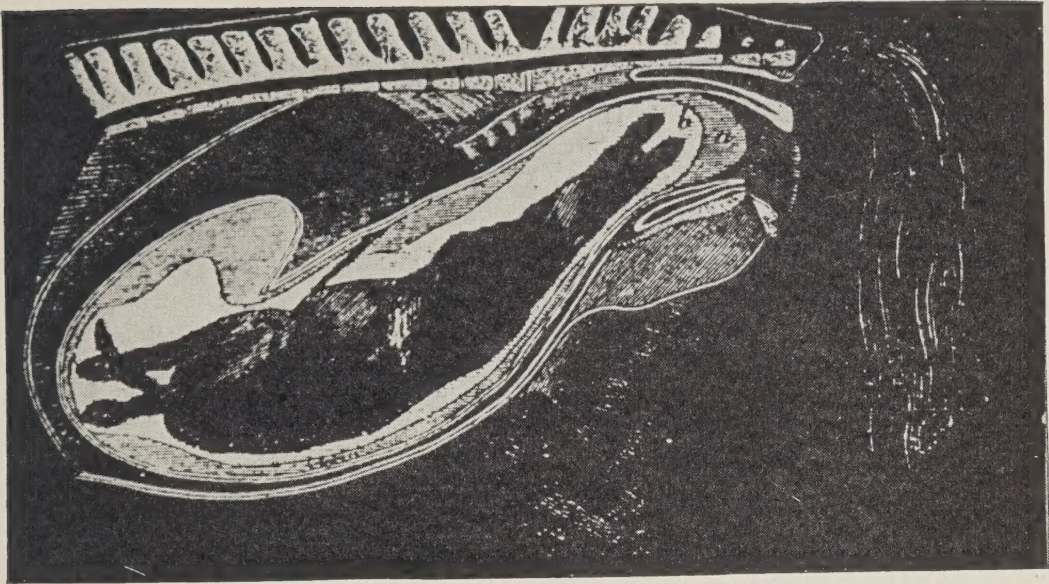
77. Act of Parturition.⁹—Parturition, or expulsion of the fully developed foetus, marks the close of the period of gestation.

The equine foetus lies on its back on the abdominal floor, with its head bent forward so that the chin rests on its chest and the forelegs are folded to its chest. Just previous to birth, the foetus changes position by making a half revolution, thus turning upright. At the same time, its head and forefeet are unfolded and stretched forward toward the pelvic opening (Fig. 13). This turning of the foetus is accomplished by contractions of the uterus and not by movements of the foetus itself; the unfolding of the limbs and head, however, are accomplished by foetal movements.

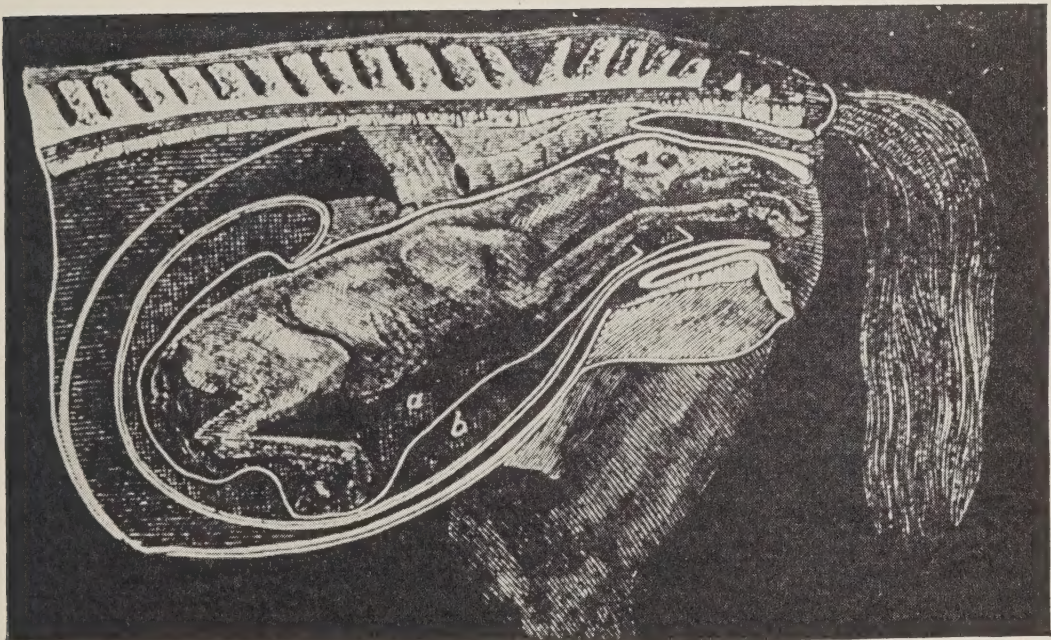
By the powerful contractions of the uterine longitudinal muscles (29), and by foetal pressure, the circular muscles of the cervix relax, allowing the head and feet of the foetus to protrude. Thus the foetus and foetal membranes serve as a wedge, which still further distends the uterus. Each contraction of the uterus is accompanied by a pain; the contractions, lasting from 15 to 90 seconds, occur at intervals of from 2 to 4 minutes. The contractions become more frequent and powerful in the final stages of parturition, and become supplemented by contractions of the abdominal muscles.

Delivery in the mare is exceedingly rapid (10–20 minutes) and violent; delivery in the ruminants, on the other hand, is very slow and may last for hours. In the mare, the chorion separates completely from the uterine wall during parturition; in ruminants, the connections are maintained to the last, therefore the circulation between mother and foetus is continued until birth. This explains why prolonged parturition in the mare usually results in death of the foetus, while the ruminant foetus may live through an exceedingly

⁹ Ellenberger, Physiology.



a



b

FIG. 13.—Revolution of the foetus prior to parturition. (After Franck, from Smith's *Manual of Veterinary Physiology*, Bailliere, Tindall & Cox, reprinted by permission.)

a, The first stage in the revolution; b, the revolution completed.

prolonged birth. Because the contractions in the mare are so violent and rapid, she becomes greatly exhausted if parturition is not accomplished within about 30 minutes.

In most animals, parturition is necessarily accompanied by more or less pain. Parturition in the bear is both interesting and odd, as she enjoys the benefit of a natural twilight sleep; parturition occurs while she is still indulging in her prolonged winter nap, and she does not awaken until the young cub is from six to eight weeks old.

78. Involution.—Involution is the change of the uterus back to normal; normally this takes place within four to five days, but if the uterus is inflamed it may take ten to twelve days.

At this time a heat, which in mares is called "foal heat," may occur. This heat occurs nine to ten days after parturition in the mare; three to four, in the sow; and eight to nine, in the cow. It is not a normal heat period, but conception usually will occur if the mare or cow is bred at this time; in the case of the sow, conception usually will not occur unless her pigs have been removed.

CHAPTER VIII

LACTATION

79. Lactation, Nature's Provision.—Mammalian young are, for the most part, quite helpless and unfit to live independently at birth; therefore, nature has providentially endowed the mother with the ability to produce milk. Nature has also seen fit to provide a food for each species that is especially adapted to its use; the milk of each species varies in composition (Table VI), and the milk of one species is seldom quite so satisfactory for the young of another.

TABLE VI
COMPOSITION OF THE MILK OF FARM ANIMALS *

Species	Water	Protein	Sugar	Fat	Ash
Cow.....	86.8	3.9	4.9	3.7	0.7
Ewe.....	81.1	6.6	4.5	6.9	0.9
Goat.....	85.6	4.3	4.5	4.8	0.8
Sow.....	82.3	5.9	3.8	6.9	1.1
Mare.....	90.7	2	5.7	1.2	0.4
Ass.....	89.6	2.3	6.0	1.6	0.5

* Chiefly from Bunge, Pathological and Physiological Chemistry, 2d English edition, translated by Starling.

In addition, nature has endowed the dam with a milk that changes slightly in composition (Table VII) as the needs of the young change. Colostrum, the milk secreted during the three or four days following parturition, is rich

in protein and ash, which act as a purgative, thereby cleansing the bowels of the new-born animal.

TABLE VII
COMPOSITION OF COLOSTRUM AND NORMAL COW'S MILK

	Water	Protein	Sugar	Fat	Ash
Colostrum*.....	77.13	12.23	2.74	2.30	1.03
Normal.....	86.8	3.9	4.9	3.7	0.7

* Race, Joseph, *The Examination of Milk*, p. 53. John Wiley & Sons, Inc., New York.

Gradually, as the young animal's needs increase, there is an increase in the amount of milk secreted. Then, as the young animal becomes able to obtain part of its feed elsewhere, there is a decrease in the amount of milk. On the other hand, as the yield increases, the percentage of butter-fat decreases, and with a decreased yield, it rises.

Originally, the cow gave only enough milk to provide for her young; but by continual selection, man has developed an animal which gives much more than is required by her young, and which from nature's standpoint is a monstrosity.

The following discussion deals with the udder anatomy and milk secretion in the cow, for man is especially interested in the cow's lacteal ability, and the process is very similar in other animals.

80. Anatomy of Cow's Udder.¹—In the cow, there are two pairs of mammary glands, each of which has a teat; at times there are other small glands and teats present which will also secrete milk if stimulated by milking. The udder is supported by the suspensory ligament, which divides the udder into two parts; this division is so complete that there is absolutely no connection between the halves of the udder. Broken-down udders are usually due to the breaking down

¹ Bitting, B. W., 12th Annual Rept., Ind. Agr. Exp. Sta., p. 36.

of this ligament. In addition, there is a fibrous tissue which surrounds the udder, and parts of which pass into the udder; this fibrous tissue forms the udder's support.

There is no wall dividing the fore and rear quarters; but the milk secreted in the fore quarter cannot be drawn off in the rear, nor that of the rear in the fore. This has been demonstrated by injecting colored matter in one quarter and trying to draw it off in the other quarter. The separation of the two quarters is explained by the fact that each teat has a milk sinus of its own, and each milk sinus has its own secondary lactiferous ducts. These ducts may be interwoven but each leads to its own milk sinus.

The alveoli at the end of the lactiferous ducts are from one thirteen-hundredth to one eight-hundredth of an inch in diameter. They occur in groups of three to five. The alveoli are lined with elongated epithelial cells, and it is here that milk secretion takes place.

81. The Blood Supply.²—The blood is brought to the udder by a pair of arteries called mammary arteries, which enter above and at the rear, one going to the right half and the other to the left half of the udder. They cannot be seen on the surface for they are deep-seated. Reaching the udder, each divides into four, two going to the rear gland, one to the fore gland, and one between the fore and the rear. If there are smaller glands, branches go to them. Within the gland, the large branches divide and subdivide, in this way reaching the alveoli.

The blood is gathered from the udder by three branches of the mammary vein and their numerous tributaries; the branches unite to form a complete circuit of veins, which pass around the udder and are called the mammary venous plexus. The mammary venous plexus has three pairs of veins leading from it; one pair, called the milk veins, lead forward and outward, and are to be seen on the exterior of the cow's abdomen; the two other pairs are deep-seated

² Bitting, B. W., Ind. Agr. Exp. Sta. Twelfth annual report.

and for simplicity may be called middle and posterior mammary veins. They lead posteriorly and centrally from the venous plexus. It is possible for the blood from any quarter to pass off through any of the passages mentioned, but its flow is directed by the position of the valves within the vessels.

In the judging of dairy cattle, a great deal of emphasis is laid on the size of milk veins and milk wells, it being considered that the longer, larger, more branching, and more tortuous they are, the greater the indication of the cow's ability to give milk. At the Oregon Agricultural College,³ it was demonstrated that the blood flow could be completely shut off from the anterior veins—milk veins,—thus causing all the blood to flow through the rear veins, and the cow continued to produce at a normal rate. Undoubtedly, however, there is a correlation between the size of the milk veins and wells and the amount of milk a cow will give, for that has been the observation of practical dairymen; and the practical stockman's observations are usually correct.

82. Theories of Milk Secretion.—Four theories have been advanced as to the manner of milk secretion, viz., (1) filtration and exudation, (2) degeneration, (3) partial degeneration, and (4) true secretion.

The first of these, an old one, is merely an assumption that the elements entering into the composition of milk gain entrance by the simple process of filtration and exudation of blood through the alveoli. This theory is easily disproven: while the ash of blood and that of milk are composed of the same elements, the elements are not present in the same proportions; and moreover, butterfat, caseinogen (a milk protein), and lactose (milk sugar) are characteristic of milk and of milk only.

The theory of degeneration⁴ is that the milk obtains its

³ Simms, B. T., Information to the writer.

⁴ Virchow, *Die Cellular-Pathologie*, Berlin.

water direct from the blood; that the epithelial cells, lining the alveoli, break loose and disintegrate, and that their products form the solid contents of milk. If this theory were true, it would be necessary that the cells of the gland be completely renewed five or more times a day, depending on the cow's lacteal abilities, in order to provide the solid constituents of milk. That this is the case appears highly improbable, because no such rapid tissue growth has ever been known.

The theory of partial degeneration, which has had wide support, is but a modification of the last-mentioned theory and it may be discarded on the same grounds.

83. The Theory of True Secretion.⁵—The theory of true secretion is that the constituents of milk are taken from the blood by the epithelial cells, but are made over. It is very likely that enzymes play an active part.

Water, in all probability, is merely filtered from the blood. The albumin and globulin proteins, present in milk in small amounts, apparently are also obtained directly from the blood.

Caseinogen, however, is undoubtedly manufactured by the epithelial cells, from protein derivatives of the body carried to them by the blood and lymph. It appears that the carbohydrates and the protein unite to form a substance called nucleo-gluco-protein; the gluco breaks away, forming the carbohydrates, and the nucleoprotein forms the caseinogen, a protein present in milk and in milk only.

Lactose ($C_{12}H_{22}O_{11}$) apparently is also a product of true secretion. Lactose is composed of one part glucose ($C_6H_{12}O_6$) and one part galactose ($C_6H_{12}O_6$), one molecule of water being lost in the formation process. Glucose is present in the blood, as is also glycogen ($C_6H_{10}O_5$), commonly known as animal starch. Supposedly, glucose or glycogen or both are taken from the blood by the epithelial cells and converted into galactose, the galactose so formed

⁵ Luciani, Luigi, Human Physiology, Vol. II, p. 502-512.

uniting with glucose, with the elimination of one molecule of water, to form lactose.

Fat is present in the blood stream, but its composition differs from that of butterfat, the chief difference being that butyric, a yellowish fat, is present in butterfat only. The supposition is that fat is taken from the blood by the epithelial cells and converted into butterfat.

The ash of milk is apparently obtained from the blood by selection, for the constituents of milk ash and blood ash are the same, although they are present in different proportions.

Both leucocytes and epithelial cells are present in milk in small numbers. The former probably wander in from the blood; the latter are possibly the products of disintegration.

In brief, the theory of true secretion is that the water, albumin, and globulin of milk are obtained directly from the blood; that the ash is obtained by selection; and that the fat, lactose, and caseinogen are the products of true secretion.

84. The Inciting Cause of Lactation.—Various hypotheses have been advanced in explanation of the inciting cause of milk secretion. All of the suggested causes may be grouped under two headings, viz., nervous influences and hormone influences. The hypothesis that a nervous influence was the inciting cause of lactation gained evidence from the fact that it is not uncommon to observe secretion in virgin animals, or even males, when subjected to the regular sucking of young animals. This secretion, called "witches milk," is, however, not a true milk. It was demonstrated by Eckhard, as early as 1855, that complete severance of the nerves leading to the mammary gland in no wise affected its secretion. Moreover, Ribbert, in 1898, transplanted mammary tissue from the normal position in a guinea-pig to its ear. The transplanted gland had lost its usual nervous connection, but during a subsequent gestation it enlarged, and later produced milk.

As a result of the above-mentioned experiments and others, investigators have practically discarded the nervous theory in favor of a chemical one, a hormone theory.

The hormone theory gained considerable support from the instance of the Bohemian pygopagus (union of the pelvis and sacrum) twins, the Blazek sisters. They were similarly affected by the pregnancy of Rosa, who gave birth to a normal child, and the breast of Josepha, as well as that of Rosa, secreted milk. This case, however, does not give conclusive evidence that the inciting cause of milk secretion is not a nervous one; for it is very probable that a nervous connection existed between the sisters.

Cristea of Vienna, however, successfully grafted pregnant females to non-pregnant ones (rats and rabbits) by suturing the peritoneum and the muscles and skin of those parts. No nervous or blood vascular connection existed; yet, following parturition of the gravid females, milk was secreted by their mates. Cristea, therefore, came to the conclusion that the non-pregnant animal was so affected by a secretory substance carried by the lymphatics from the pregnant animal.

While most investigators are agreed that a hormone furnishes the necessary inciting stimulus for milk production, they are not agreed as to the organ from which it is secreted. The ovaries, uterus, placenta, foetus, and corpus luteum have all been suggested.

That either the ovaries or pregnant uterus furnish the necessary stimulus seems highly improbable from the fact that extracts of those organs from pregnant animals, when injected into non-pregnant ones, gave negative results. The injection of foetal extracts, however, gave positive results; fifteen injections, spread over fourteen days, produced a condition in the non-pregnant rabbit very similar to that of the rabbit eight days pregnant.

It has been maintained that development of the foetus furnishes the stimulus to development of the mammary

glands, but that the foetus itself furnishes an inhibitory influence which is removed by parturition. This belief has gained support from the fact that females which abort frequently secrete milk. On the other hand, it is not uncommon for females to secrete milk before parturition occurs.

Objection is offered to the foetal theory on the ground that virgin females and even males will secrete milk if suckled persistently; but, as already mentioned, this secretion is not deserving of the name of milk.

It has conclusively been shown that injected extracts of the corpus luteum would cause the immediate secretion of milk from virgin females; hence the corpus luteum has also received considerable attention. According to Smith,⁶ however, the corpus luteum frequently disappears during the latter half of pregnancy. Extracts from the placenta, the involuting uterus, the pineal gland, the posterior lobe of the pituitary gland, and the mammary gland have all given very positive results.

That a hormone furnishes the inciting cause of milk secretion is, therefore, quite fully established; but which organ secretes the vital hormone is still unknown. It is highly probable that several hormones, some acting as accelerators and others as inhibitors, are involved.⁷

85. Control of Milk Secretion.—Milk secretion is controlled physiologically by hormones, nerves, and the plane of nutrition. The pituitary body, pineal gland, corpus luteum, involuting uterus, thymus glands, active mammary gland, and the developing uterus all secrete hormones which influence milk secretion.

It is possible that the nerves may affect milk secretion by any of the following methods:

⁶ Smith, F., *Manual of Veterinary Physiology*, p. 698.

⁷ For a more complete discussion of the inciting cause of milk secretion, the reader is referred to the following authorities:

Marshall, Francis H. A., *The Physiology of Reproduction*, Chap. XIII.

Ernst, Mohler and Eichorn, *Milk Hygiene*, Chap. II.

Luciani, Luigi, *Human Physiology*, Vol. II, p. 512-517.

(1) Psychic influences—fright or anger cause a decrease in the milk flow.

(2) Reflexes from local stimulations—massage by either milking or suckling stimulates milk secretion.

(3) Reflexes from the genital organs—cystic ovaries cause a decrease in the milk flow; palpation of the ovaries (treatment for this condition) however, is followed by an increase.

(4) Motor influences—the stimulation of certain nerves will cause stiffening of the nipple.

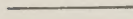
(5) Vasomotor influences—the section of certain vasomotor nerves will accelerate milk secretion.

(6) Trophic and functional influences—since milk secretion is most abundant following parturition, and menstruation does not manifest itself (in those females subject to menstruation) during this period, it is held that there is a correlation between the two.

(7) Secretory influences—it is held by some that there are specific secretory nerves which may influence the secretion of milk.

A high plane of nutrition, especially if the feed is highly carbonaceous, inhibits the milk flow; while, on the other hand, slight under-feeding acts as an accelerator.

PART III



HEREDITY

CHAPTER IX

INHERITANCE

86. Heredity and Inheritance Defined.—Heredity and inheritance are commonly used with similar meaning and sense, i.e., the resemblance of offspring and parents; but heredity is here used with a wider scope as to its abilities and possibilities.

Heredity is frequently spoken of and defined as “the past living in the present.” Again, its action is summed up in the phrase, “like begets like.” Neither of these expressions is quite adequate: first, they limit heredity to narrow bounds, not allowing for variation; and second, they attribute greater possibilities to it than it possesses. Strictly speaking, “like tends to beget like” (*Frontispiece*); but like cannot beget like, for no two individuals are identical. The above definitions more properly define “inheritance,” which is “the ability of parents to transmit characters to their offspring” (Fig. 14).

Heredity, on the other hand, recognizes and allows for variation. Heredity is often used to include and account for all the resemblances of related individuals. This resemblance is not entirely due to heredity; for the association of the offspring with its parents at any acquired work would be bound to influence the offspring's mental traits. For instance, the Shepherd dog was originally used to care for the flocks and herds; but during the war, owing to his great intelligence, he was used to guard munition works; this was acquired work, not his natural work or business in life, but any little puppies playing about and growing up under this

environment would involuntarily come to resemble their parents in their ability to distinguish workmen from possible spies or other marauders. In humans, it is very possible for parents to influence children by tradition, e. g., in developing punctuality, neatness, political aspirations, or a desire for business or professional life.



FIG. 14.—A five-day old Hackney foal showing remarkable action. The result of inheritance. (Courtesy *The Farmer's Advocate and Home Magazine*.)

Thomson¹ defines heredity as, “the organic relation between successive generations—a relation which secures persistence of characteristics and yet allows new ones to emerge.” This definition accounts for the resemblance between offspring and parents, but does not account for all their resemblances, and yet allows for the differences that do arise.

As so aptly pointed out by Thomson, it is a mistake to

¹ Thomson, J. A., *The System of Animate Nature*, Vol. II, p. 478.

think of heredity as Heredity, for it is not a mysterious, invisible, and powerful force at play but simply one of nature's many far-seeing methods of providing a continual habitation of the earth by man, beast, and plants, without such sudden alterations of type of any one species, breed, or individual as might be detrimental to the other inhabitants of the earth and to the continuity of all. It is a flesh and blood union binding one generation to the other, thus providing for the continuity of the race by means of "the continuity of the germ plasm."

87. Importance of Heredity.—An individual's ultimate attainment in life, as regards its individual constitution and abilities, is not only determined by heredity but by its environment and training as well. Walter ² represents life as a triangle, heredity forming the base and environment and training forming the two sides, these three factors determining what we are, what we have and what we do, respectively.

Heredity is, therefore, fundamental, environment and training being built upon it. Thus, the scope of their influence is dependent upon the limits of heredity; and, on the other hand, the fulfillment of heredity's many possibilities is more or less dependent upon its being suitably complemented by environment, while the maximum development of both hereditary and environmental influences may at times be dependent upon their being duly complemented by training. For instance, Fig. 15 is an illustration of the grand champion fat wether at the 1923 International Livestock Exposition. This animal never could have attained such an honor had not his heredity been broad enough to support his development as governed by the environmental factors, feed, care, and fitting. It is very likely that the University of California, which was his owner, had other lambs, subjected to a similar environment, which did not attain the same goal simply because their heredity was not broad

² Walter, Herbert E., *Genetics*, p. 2.

enough; and, on the other hand, his reaching the full scope of his hereditary possibilities was subject to his being placed under a favorable environment, that of being placed in the hands of a master craftsman.



FIG. 15.—Grand Champion wether at the 1923 International Livestock Exposition. The result of heritage plus environment.

Carrying the analysis further, two foals, belonging respectively to the Belgian and American Saddle Horse breeds, might be dropped on the same farm and reared under the same environment and training; but the development of each would be limited by his heredity. The Belgian colt might be trained just as diligently under the saddle, but he would never accomplish the five gaits; and the

saddle colt might be taught just as carefully to lift a load, but he would never acquire the knack. On the other hand, if Sinbad (Fig. 16) the beautiful five-gaited saddle horse, champion at the National Horse Show in 1921, had not been placed under a suitable environment and training, he would never have been champion. Heredity is, therefore, the



FIG. 16.—Sinbad, Champion five-gaited saddle horse at the 1921 National Horse Show. The result of heritage plus environment and training. (Courtesy *The Field Illustrated*.)

foundation which determines the kind and the success of the structure to be built upon it, but, like all foundations, it remains a foundation only unless the structure is built.

88. Regulation of Development.—It is very evident that there is something within the fertilized egg which controls the developing organism, with regard to the time, rate, and extent of development of the various characters. In

sheep, for example, the lamb teeth are all present the first year; in the shearling, the center incisors are replaced by two permanent ones; in the two-shear, the second pair are replaced; in the three-shear, the third pair; and as a four-year-old the sheep exhibits a full mouth. There is little variation about nature's regularity in matters of this kind. Environment may accelerate or retard the appearance of certain characters, but in general they remain quite fixed.

It is also a well-recognized and known fact that offspring tend to resemble their parents; e. g., a Hereford cow when bred by a Hereford bull will produce a Hereford calf. The physiology of reproduction furnishes a physical basis for heredity, namely, the germ cells, one of which is derived from either parent. But just how is this correlation between parent and offspring brought about? The Hereford cow and bull mentioned above do not give their own white faces to the calf, as a mother might hand down a string of pearls to her daughter.

Many theories have, from time to time, been advanced to explain nature's method of accomplishing heredity. Two of the older ones are of especial interest, namely, Darwin's theory of pangenesis and Weismann's theory of the continuity of the germ plasm; for they are conflicting and each has served as a foundation on which many later theories have been built.

89. Darwin's Theory of Pangenesis.—When Darwin formulated his theory, it had long been known that body growth was accomplished by cell division, and that by this process the fertilized egg cell developed into a fully matured individual, composed of its various physiological systems, each built from groups of similar cells. Darwin was not the first to attempt an explanation of heredity; but he was the first to set forth an hypothesis which attracted world-wide attention.

In brief, Darwin's theory³ is that the somatoplasm

³ Darwin, *Animals and Plants under Domestication*.

(body cells) throws off gemmules which are dispersed throughout the whole system; some of them develop into cells like those secreting them, while others temporarily remain dormant, gathering within the sexual glands, where, when duly collected and arranged within the germ cells, they may be secreted to form the next generation. If this theory is to be accepted, the white face of the Hereford calf can be explained as being due to the fact that the cells constituting the father's and mother's white faces give off gemmules or particles of themselves, which, on collecting within the sexual organs, are passed on in the germ cells to the new individual.

Darwin then states: "I am aware that my view is merely a provisional hypothesis or speculation; but until a better one is advanced it will serve to bring together a multitude of facts which at present are left disconnected by any efficient cause."

It would seem from this that Darwin was not entirely satisfied with his own hypothesis.

90. Weismann's Theory of Continuity.—Weismann⁴ brought forward a theory entirely opposed to the one expounded by Darwin. According to this theory, the germ plasm of multicellular organisms contains germ cells, which Weismann calls "idants," or nuclear rods. Each idant is composed of ancestral germ plasms called "ids," each of which is composed of thousands or hundreds of thousands of "determiners"; and the determiners in turn are built up of the ultimate units or actual carriers of vitality, called "biophors." The biophors are of various kinds, each kind corresponding to a different constituent of the various cells. The determiners are made up of various but perfectly definite numbers and combinations of these biophors, each of which is then the primary constituent of a particular cell or group of similar cells, e.g., the epithelial cells.

⁴ Weismann, *The Germ Plasm*, Pt. I.

With this theory, we can compare the hereditary material—made up of parts and these of smaller parts—to a building constructed of sides, ends, floor, and roof, each of which is composed of various kinds of brick, stone, mortar, and wood, while these materials in turn are formed from their various ingredients. Starting with the simplest units of construction, and building up, we have:

(1) Biophors—representing the different characters or qualities of the cells.

(2) Determiners—built of biophors—representing the constituents of a particular cell or group of similar cells.

(3) Ids—built of determiners.

(4) Idants—built of ids.

Supposedly, the determiners control the cell by breaking up into biophors, which enter the cell body by pores in the nuclear membrane. Here they multiply, arrange themselves according to their internal forces, and thus determine the histological structure of the cell. This, however, they do only after undergoing a certain definite period of development, throughout the duration of which they reach the cell they are to control.

Each determiner reaches its proper place in the body as a result of its having a definite position within the id, which possesses an inherent and perfectly definite structural arrangement. Development, therefore, depends upon the gradual disintegration of the id. The id splits into smaller and still smaller groups of determiners as the individual develops; thus, in place of the original million different determiners—of which, supposedly, each id is composed—each daughter cell, after the first cleavage, would possess only half a million, the next a quarter of a million, the next an eighth of a million, and so on until only one kind of determiner remained for each kind of cell—the cell or group of similar cells into which it is to develop and which it is to control during development.

Weismann maintained that the body plasm was the out-

growth from the germ plasm rather than the germ plasm from the body plasm. He maintained that hereditary material is passed on from one generation to another and the body plasm merely acts as its host for a time but cannot alter the germ plasm's character. This is known as his theory of the "continuity of the germ plasm."

91. Comparison of the Two Theories.—The two theories of heredity just explained are not only opposed but they raise the whole question of "the inheritance of acquired characters" (Chapter X). With Darwin's theory, it is easy to explain the inheritance of acquired characters; but with Weismann's, it is somewhat more difficult to understand how any modifications of the parents may be passed on to succeeding generations.

The practical stockman may say that it matters not to him whether heredity is controlled by pangenesis or continuity; all he cares about is the rearing of a good horse, steer, or milk cow. But it is of vital importance to him in selection of herd sires; for if he accepts the former theory he will pay far more attention to development and environment and less to bloodlines, than if he accepts the latter.

92. Chromosome Theory of Heredity.—It is now quite obvious that the hereditary determiners are contained within the nuclei of the sperm and egg cell, and, furthermore, that the chromatin material contains or is composed of these determiners, supposedly as so many "genes." There are six outstanding reasons for believing that the secrets of heredity lie within the chromosomes:

(1) Despite the fact that in some species the ovum is 100,000 times the size of the sperm cell, they are of equal importance in their hereditary influence, as has been frequently proven by making reciprocal crosses.

(2) The only similar features possessed by the two cells are the chromosomes.

(3) The chromosomes are reduced in number by one-

half during the process of maturation, and the original number is restored by fertilization.

(4) Maturation is practiced by germ cells only, and during the processes of maturation and fertilization—with their many complicated changes—no other part of the cell plays such a consistent and persistent part. The nuclear chromatin content, previous to cell division, arranges itself into a definite number of straight or curved rods, called “chromosomes.” It is assumed that each chromosome contains a definite number of character-determining factors, or genes, the number of which in a given cell might run into the thousands. Each gene is characteristically different and has a distinct function to perform. Not only is each chromosome made up of a definite number of genes, but each gene has an exact location within the chromosome and it always occupies that place; thus, being always in the same place, they are able during disintegration to control heredity in exactly the same way at all times.

(5) Certain chromosomes in the zygote have been identified with certain characters in the adult; and in sex determination (60) it is quite evident that the presence of a certain chromosome or pair of chromosomes is responsible for the individual's becoming a female, while its absence is responsible for the individual's becoming a male.

(6) Furthermore, it has usually been noted that pronounced changes in the individual follow abnormal distribution of the chromosomes, which is the result of imperfect cell division. In specific cases, pieces of chromosomes or even whole chromosomes have been lost, and usually the individuals exhibiting such deficiencies, upon development, lack certain characters.

Because of the foregoing reasons, most present-day biologists believe that the chromosomes are the moderators of heredity. It is noteworthy to remark here that the present-day conception of heredity is not far removed from the theory advanced by Weismann. But just how the chromo-

somes contain and exercise this control is still unknown. It has been suggested that enzymes play the fundamental rôle in heredity.

93. The Hereditary Bridge.—At one time it was thought that heredity was not completed until birth, but to-day it is an avowed fact—regardless of which theory of heredity is accepted—that the zygote resulting from the two sex gametes contains all the hereditary material, and that heredity is completed at fertilization. This single fertilized egg cell is the actual and only bridge or connection between parents and offspring, and because of this it is spoken of as the “hereditary bridge.”⁵ This is as wonderful as any of nature’s many phenomena, when we consider that all of the many varied characters that go toward making an animal, such as the horse, for instance, are packed in this one little cell about $\frac{1}{125}$ of an inch in diameter; and furthermore that the sperm cell, which is many thousand times smaller than the egg cell, is, however, of equal importance in hereditary determination.

94. Control of Heredity.—The livestock breeder’s aim is to gain a maximum control over heredity. His ambition in mating animals is to exercise such control that only the most desirable characters of each may be transmitted and the undesirable may not be transmitted to the future offspring. However, if one considers (admitting the chromosome theory) that the determiners of the future animal’s various characters are wrapped up in the possible millions of genes, the genes in some 20 to 50 chromosomes, and the chromosomes in cells from $\frac{1}{125000}$ to $\frac{1}{125}$ of an inch in diameter, one can appreciate how extremely difficult a control of heredity would be. But these two germ cells come from the individual’s parents, and it is by means of them that the individual inherits all its anatomical, physiological, and psychological characters. Thus, by making a close study of the individuals used for breeding purposes, regarding not

⁵ Walter, Herbert E., *Genetics*, p. 27.

only their own individuality but their ancestors' individuality as well, and by mating only those containing the maximum of desirable characters, the breeder may obtain at least a partial control of heredity.

95. Types of Inheritance.—The transmission of characters from parents to offspring follows three rather distinct types, viz., Mendelian, blending and prepotent. Mendelian inheritance is of the type whereby certain characters of either parent are transmitted intact to the offspring, e.g., in the crossing of true polled and horned cattle, the offspring are polled. Blending inheritance is of the type whereby, when individuals possessing opposed characters are mated, the offspring exhibit characters that are midway between those possessed by the parents; e.g., if a Morgan mare be mated to a Percheron stallion, the offspring will, in most cases at least, be of a size midway between that of its two parents—in size it will represent a blend of characters. Propotent inheritance is of the type whereby one parent tends to stamp its characters on the offspring to the exclusion of the other's; this type of inheritance is best illustrated in the mating of a mongrel to a good purebred, the offspring tending to take more strongly after the characters of the purebred.

Each of these types of inheritance will be discussed more in detail in the subsequent parts of this chapter. In studying them, however, the impression should not be formed that they are opposed, for Mendelism is at play in both blending and prepotent inheritance and blending inheritance is at work in prepotent inheritance.

1. MENDELIAN INHERITANCE

96. Mendel.—Gregor Johann Mendel, an Austrian monk and teacher of the physical and natural sciences in a monastic school at Brünn, Austria, made one of the greatest—if not the greatest—contributions ever made to the

study of genetics. Brief accounts of his work were published in 1865 in the proceedings of a local scientific society, after which they remained unheeded until rediscovered simultaneously, thirty-five years later, by Tschermak of Austria, De Vries of Holland, and Correns of Germany.

For eight years, by the crossbreeding of peas, Mendel made a series of hereditary studies regarding the behavior of contrasted characters. From these studies, he drew some conclusions which are now known as Mendel's Law of Heredity, and which deal with the inheritance of contrasted or allelomorphic characters. The work, while carried on with peas, has been confirmed as holding true in a large number of characters for animals as well.

97. Mendel's Objective.—Mendel's close observations of crossbreeding led him to believe that certain ancestral characters reappeared with a certain numerical regularity when the hybrids of the first, second, and succeeding generations, respectively, were interbred. He, therefore, set out (1) to ascertain, if possible, the number of different forms under which the offspring appear, (2) to arrange these different forms with certainty according to their separate generations and (3) to ascertain definitely their mutual numerical relationship.

98. Mendelian Terms.—Mendelism necessarily introduces a certain terminology, which it seems advisable to set forth before proceeding with the discussion.

Character is one of the many details of form or performance which, taken collectively, constitute the individual. Ordinarily, color is thought of as a character.

Factor or gene, is a single element of the germ plasm, the presence of which, with development, gives rise to some character in the individual. It is not essentially different from Weismann's "id."

Genotype is an individual's constitution as regards the factors composing its germ plasm, i.e., the characters it will transmit to its offspring.

Phenotype is an individual's constitution in regard to the physical or obvious characters possessed by the individual.

Allelomorphic is one of a pair of contrasted factors, e.g., the factor for the polled or horned character in cattle.

Homozygosity (*adjective*, homozygous) is that condition in which a given genetic factor is doubly present within the individual; e.g., if a purebred Aberdeen-Angus bull is used on a purebred Galloway cow, the resulting offspring is a crossbred; but it is homozygous for the polled character and will breed true in that respect.

Heterozygosity (*adjective*, heterozygous) is that condition in which a given genetic factor is only singly present within the individual; e.g., if a purebred Aberdeen-Angus bull is used on a horned Shorthorn cow, the resulting offspring will generally be polled (phenotype) but the polled character will be only singly present, and the hybrid will produce gametes, one-half of which will possess the polled factor and one-half the horned factor.

99. Dominance.—If a pure polled bull is used on horned cows (or *vice versa*), the resulting hybrids are not midway between the two parents; they always possess the polled character. Characters which are transmitted entirely or almost unchanged in the hybridization, as the polled character, are termed the dominant characters; and those which recede from view, as the horned character, are termed the recessive characters.

Dominance, therefore, is a property possessed by certain characters, by virtue of which, when individuals possessing allelomorphic characters are interbred, the resulting offspring in the first (F_1) generation will all exhibit the dominant character; i.e., when pure polled and horned cattle are crossed, the hybrids will all exhibit the polled character, since it is dominant to the horned character.

Experiments, as the result of reciprocal crosses, have plainly shown that it is immaterial whether the dominant character belongs to the male or female parent. This is of

special importance; for it is frequently thought that one of the parents (on account of its sex) has a predominating influence on the resulting descendant.

100. Successive Generations of Hybrids.—When the above mentioned hybrids are interbred, the recessive (horned) as well as dominant (polled) character will appear in the second (F_2) generation. Among large numbers they will appear in quite definite proportions, so that among four individuals of the second generation three will exhibit the dominant character, to one receiving the recessive character; i.e., three polled individuals to one horned.

If the horned individuals of the F_2 generation are interbred, the resulting offspring will exhibit the horned character. On the other hand, if the polled individuals of the F_2 generation are interbred, they will continue to segregate. In segregating, one-third will breed true as regards the polled character, while two-thirds will breed polled and horned individuals in the three-to-one proportion. In successive generations, segregation will continue as above outlined.

101. Mendel's Laws.—From his detailed work, Mendel formulated the two laws which follow:

(1) *The law of segregation* arises from the above results; it may be stated thus: Since the F_1 generation, when interbred, produce offspring in the 3:1 proportion, viz., 3 polled; 1 horned, it is clear that genes contributed by the two parents, each of which has a definite rôle in the determination and development of characters, separate in the germ plasm of the offspring without having influenced each other.

The law of segregation may be more clearly understood by studying the accompanying diagram (Fig. 17). In this diagram, P denotes the dominant character, polled; p , the recessive character, horned; Pp indicates that the phenotype is polled but breeds as a hybrid, producing both polled and horned germ cells; while PP and pp denote purity regarding breeding powers, each producing only one kind of germ cell.

(2) *The independent assortment of the genes* is the second law drawn from Mendel's work; it is illustrated when individuals possessing two or more pairs of contrasted characters are mated; e.g., the Aberdeen-Angus and Shorthorn cross involves coat color and horned characters, with the result that the F_1 offspring are black and polled, while in the F_2 generation segregation for each pair of characters behaves independently. The second law, therefore, may be stated thus: Two or more pairs of allelomorphic genes may segregate independently in the germ plasm of the hybrid

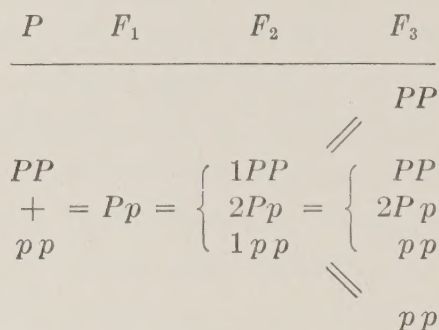


FIG. 17.—Diagram illustrating the genetic composition of the various generations when crossing polled and horned cattle.

and be combined in the subsequent generation in all possible combinations, the number of these combinations being governed by chance only.

102. Mendel's Theory.—Mendel's theoretical explanation of the above is that when plants or animals possessing contrasted characters are interbred, these contrasted characters do not blend in the offspring's germ cells, but 50 per cent of the hybrid's germ cells contain the dominant character and 50 per cent the recessive character. The hybrid, therefore, yields two kinds of germ cells, or rather, germ cells differing in regard to the characters transmitted, and thus when the hybrids interbreed a chance production takes place (Fig. 18).

Mendel assumed a genetic purity for a given single factor, which seems justifiable in the light of present-day

biological knowledge; for during the process of maturation, the chromosomes apparently line up in pairs, each pair supposedly carrying corresponding factors; a reduction follows, due to a longitudinal division, and one-half of the chromosomes are lost. At this stage, gametes (germ cells) are produced, each of which carries only one-half the normal number of chromosomes, the missing one-half being again restored by fertilization. Therefore, when the two gametes unite, either two opposed factors are present or one is doubly present within the zygote. If then, as in Fig. 18, two gametes of the P type unite, the one factor is doubly present and the individual becomes homozygous for a given factor. On the other hand, if two gametes like P and p unite, the two opposed factors are present and the individual becomes heterozygous for a given factor.

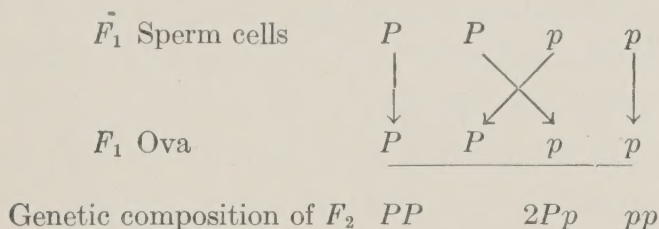


FIG. 18.—Diagram illustrating Mendel's theory.

103. Polled Breeds of Cattle Developed.—It is by this working of Mendelism that some breeds of polled cattle have been developed. The polled Herefords were largely developed through the efforts of Warren Gammon, Des Moines, Iowa. In the year 1901, Mr. Gammon sent out letters to 2500 Hereford breeders, making inquiry regarding polled cattle. As a result he located sixteen polled Herefords, six bulls and ten cows. When these were interbred the F_1 generation was nearly 100 per cent polled; and when polled bulls were used on horned cows, from 50 to 75 per cent of the offspring were polled. By continued breeding and selection, the polled character became fixed so that in less than two decades a fully established and prominent strain of polled Herefords was in existence.

104. Mendelism Becomes Complicated.—Domestic animals are valued by man for the desirable characters they possess, e.g., the meat animal for its ability to produce meat, the dairy cow for her ability to produce milk, and the horse for its ability to perform work; and the question arises: How far can we go with Mendelism as a guide in animal breeding? If we could take these various qualities as a whole and expect them to be transmitted as a whole after the simple Mendelian fashion, then livestock breeding would become remarkably simple. If we could use a beefy bull, which would dress 70 per cent, in his prime, on scrub cows dressing 40 per cent, in the best of form, and expect that the resulting offspring would all be patterns of the old bull (assuming beefiness to be the dominant character), and that when these offspring were interbred they would reproduce after the Mendelian manner, then livestock improvement would be remarkably rapid and easily attained. The complication arises in the large number of factors of which such qualities are developed, and as yet scientists have been able to differentiate but few of these factors. A better understanding of the behavior of Mendelism in livestock and of its complexity can be obtained by a review of some of Castle's detailed work on the behavior of Mendelism in guinea-pigs' coats.⁶

105. Mendelism in Guinea-Pigs.—In guinea-pigs, the black coat color is dominant to white; short hair to long; and rough hair to smooth. A short-haired, dark, smooth guinea-pig crossed on a long-haired, rough, albino guinea-pig produced offspring which in the F_1 generation were all short-haired, dark, and rough, these being the three dominant characters, two being derived from one parent and one from the other. When the F_1 individuals were interbred, the F_2 generation was of eight distinct types, two being like their respective grandparents, one like the F_1 individuals, and the other five showing new forms, viz., (1) short white

⁶ Castle, W. E., The Carnegie Institution of Washington, 23 and 49.

rough, (2) short white smooth, (3) long white smooth, (4) long dark rough, and (5) long dark smooth. Of the eight classes of phenotypes, the one possessing the three dominant characters, short, dark, and rough—the only type manifest in the F_1 generation—was the largest; while those exhibiting the three recessive characters, long, white, and smooth, formed the smallest class. Over large numbers, these two classes should appear in the proportions of 27:1, and of the 27 triple-dominants, 26 should be heterozygous.

The above results in the F_2 generation may be illustrated by the checkerboard system (Fig. 19). In following

		EGGS							
S P E R M S		SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr
	SBR	SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr
	SBr	SBR	SBR	SBR	SBR	SBR	SBR	SBR	SBR
	SbR	SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr
	sBR	SBr	SBr	SBr	SBr	SBr	SBr	SBr	SBr
	Sbr	SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr
	sBr	SbR	SbR	SbR	SbR	SbR	SbR	SbR	SbR
	sbR	SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr
	sbr	sBR	sBR	sBR	sBR	sBR	sBR	sBR	sBR
		SBR	SBr	SbR	sBR	Sbr	sBr	sbR	sbr

FIG. 19.—Checkerboard illustration of calculating a Mendelian F_2 expectation when three pair of characters are involved.

this explanation, it must be kept clearly in mind that the types of gametes, as indicated on the two sides, represent the combinations of genes that would be produced, and that their union with other genes, resulting in a zygote as indicated by the squares, is such as would follow chance matings over large numbers.

The above, gathered together in genotypic and phenotypic classes, is as in Fig. 20.

Genotypic ratio:

1	SSBBRR	SSBBrr	SSbbRR	ssBBRR	SSbbrr	ssBBrr
	ssbbRR	ssbbrr				
2	SSBBRr	2SSBbrr	2SSbbRr	2ssBBRr	2Ssbbrr	2ssBbrr
	2ssbbRr					
2	SSBbRR	2SsBBrr	2SsbbRR	2ssBbRR		
2	SsBBRR	4SsBbrr	4SsbbRr	4ssBbRr		
4	SSBbRr					
4	SsBBRr					
4	SsBbRR					
8	SsBbRr					

Phenotypic ratio:

27 SBR + 9SBr + 9SbR + 9sBR + 3Sbr + 3sBr + 3sbR + 1sbr

FIG. 20.—A trihybrid Mendelian F_2 expectation arranged in their genotypic and phenotypic classes.

106. Fixation of New Types.—By this crossing, six new forms were created, one appearing in the F_1 generation and five in the F_2 generation. One can readily appreciate how increasingly difficult it becomes to fix the new types obtained by crossing when the number of dominant characters in the selected type increases. The only way this can be done is by continued experimental breeding until segregation no longer continues.

If the F_2 individuals produce eight types of gametes in equal numbers (as they would over large numbers), chance fertilization among them should produce eight corresponding types of individuals in the proportion 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1. From a total of 64, only one genetically pure individual should be produced from each of the eight differ-

ent classes. Of the eight classes, the three dominant characters are exhibited by the numerical class, 27; two dominant characters are exhibited by the three numerical classes, 9; and one dominant character by the three numerical classes, 3; while only recessive characters are exhibited by the numerical class, 1. The first seven classes will, on the average, each produce one genetically pure individual, and the latter class, possessing only recessive characters, will breed true from the start. It requires no continued experimental breeding to fix its type, as will be required by all the others.

107. Color in Cattle and Mendelism.—Color inheritance in cattle is extremely complicated, and while considerable work has been done in this connection much is as yet unknown.

Black, however, is plainly dominant to red. The Galloway, Aberdeen-Angus, and Holstein-Friesian cattle have all been derived from stocks containing many red animals, and all of these breeds at the present time occasionally drop calves showing the red color, the red thereby behaving as a recessive. Furthermore, Lloyd-Jones and Evvard,⁷ in using a roan (red-pigmented) Shorthorn bull on purebred black Galloway cows, obtained 11 offspring all of which were black-pigmented.

Red in cattle behaves as a recessive character, as noted above. This is also apparent from the fact that among Shorthorns red $\times$ red matings so seldom produce any other than red offspring. The few exceptions can be looked upon as herd book errors, for it is very easy to call an animal red when it is a dark roan or a red with a few white hairs.

White in cattle is an extremely difficult color to explain; apparently it consists of several different varieties. Apparently, white in the Shorthorn is never pure, for the face bristles, eyelashes, and ears always carry a few red hairs. There also exists the spotted red and white Shorthorn,

⁷ Lloyd-Jones and Evvard, Iowa Research Bul. 30.

which is presumably of a different genetic composition, possibly somewhat similar to the spotted Ayrshires and Holstein-Friesians. Another type of white is found in the white Park cattle of Britain, which always have colored ears. It is known that some of these herds were of mixed origin, and occasionally they drop colored calves, even though none of these calves have for years been retained for breeding purposes. The white face of the Hereford, which is almost invariably stamped on the offspring when the Hereford is crossed with either other breeds or species, is another type of white.

Still another type of white occurring in cattle, although rarely, is the albino, which is due to an entire absence of pigmentation. Mr. Kaslow, Mora, Minnesota, developed a herd of this kind.⁸ The first albinos, a bull and a heifer, were obtained by using a purebred Holstein-Friesian bull on grade Holstein-Friesian cows. The parents were of the normal black and white color. Unfortunately, the sire of these albino calves was killed before the calves were born and thus further breeding to him was impossible. It would appear that albinism was recessive to the spotted condition, and that the chance matings of two recessive factors had resulted in the albinos. Such being the case, the F_1 bull when mated to spotted females should have thrown pigmented offspring; but such was not the case. He, used on the normal-colored grade Holstein-Friesian females, threw two albino calves. Four albino females mated to a normal-colored Holstein-Friesian bull dropped one pigmented and three albino calves. This latter fact would indicate that the albinism is dominant to the pigmented condition and it leaves an extremely difficult condition to account for. The albinos were entirely white with absolutely no pigmentation and with pink eyes; they were extremely sensitive to light.

Roan is another color in cattle which is extremely dif-

⁸ Detlepen, J. A., Journal of Heredity, Nov. and Dec., 1920.

ficult to explain; in reality it is not a color but a pattern, due to a sprinkling of white hairs in a pigmented coat. Roan is a characteristic Shorthorn color and it varies extensively, running from what at first glance appears to be white to the dark colorations very close to a red. Another type of roan met with in cattle is the blue-roan or blue-gray produced by using white Shorthorn bulls on black Galloway or Aberdeen-Angus cows.

Still other cattle colors met with are the dun, brindle, and fawn, which is the popular color in Jerseys and Guernseys. In Mendelian studies among Jerseys, Hooper⁹ found the solid color to be dominant to broken color, and the black tongue and switch dominant to the white tongue and switch. The mating of 436 solid-colored cows to broken-colored bulls produced 257 solid-colored calves and 179 broken-colored ones; while 500 matings of solid-colored cows and bulls produced 425 solid-colored calves and 75 broken-colored calves.

By using a purebred white Shorthorn bull on purebred Galloway cows, Lloyd-Jones and Evvard¹⁰ obtained 28 F_1 calves, of which 27 were blue-gray and 1 was red-roan. A roan Shorthorn bull used on purebred Galloway cows threw 11 calves, 5 of which were blue-gray and 6 black. When the blue-gray F_1 generation (Fig. 21) was interbred, of the 20 individuals produced, 11 were blue-gray, 1 black, 1 red-roan, 4 solid red, and 1 red and white, while 3 were white with black extremities. The last color type (Fig. 22) is very similar in appearance to the white Park cattle of Britain. When Shorthorn and Galloway cattle are crossed, Lloyd-Jones and Evvard consider that three sets of allelomorphous characters regarding color are at work; (1) black and red-pigment, due to the presence or absence of the dominant factor B for black; (2) roan and absence of roan, due to the presence or absence of the dominant factor N for

⁹ Hooper, J. J., Ken. Bul. 234.

¹⁰ Lloyd-Jones and Evvard, Iowa Research Bul. 30.



FIG. 21.—A blue-gray bull, the result of a roan Shorthorn-Galloway cross.
(*Courtesy Iowa Agricultural Experiment Station.*)

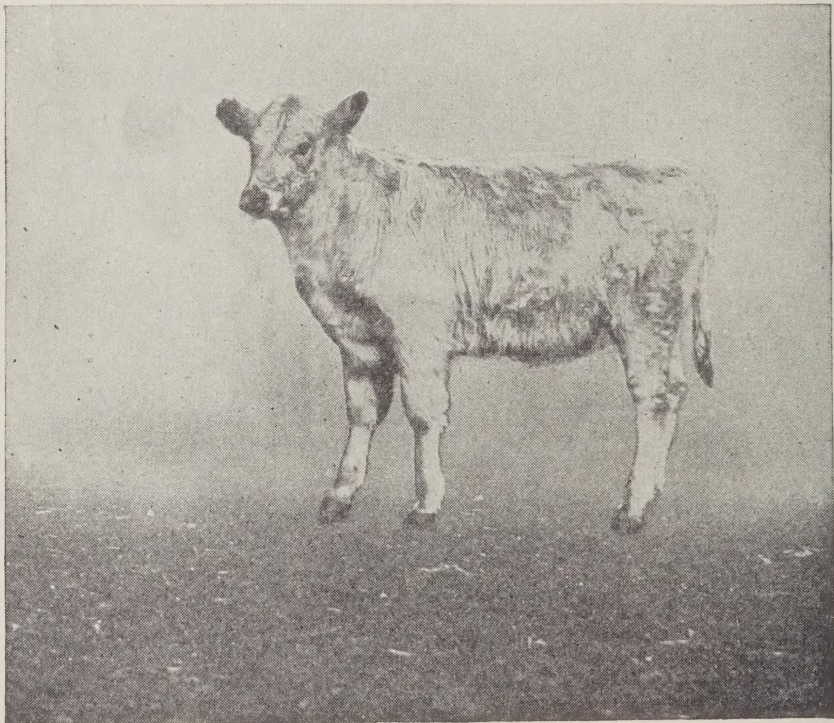


FIG. 22.—One of the F_2 generation, the result of the roan Shorthorn-Galloway cross. (*Courtesy Iowa Agricultural Experiment Station.*)

roan; (3) extended and restricted pigment, affecting red and black alike, due to the presence or absence of the dominant factor *E* for pigment.

As already stated, color inheritance in cattle is extremely complicated; for while in Galloway-Shorthorn crosses the above interpretation of colors works out with remarkable closeness to the Mendelian formula, yet when applied to other crosses it may fail to work. In the case of a Hereford-Galloway or Hereford-Aberdeen-Angus cross, the offspring is black in body but has a white face. The dominant factor *B* carried by the Galloway or Aberdeen-Angus has superseded the Hereford's red, as allowed for by the first pair of allelomorphic sets of conditions; but the Hereford's white face has supplanted the Galloway's black one, which should not take place if, in this case as in the Shorthorn-Galloway cross, the white was due to a recessive extension factor *e*. In this case, the Hereford's white face appears to be dominant to all other colors. It is more than likely that in this case, the white face is due to a dominant pattern factor; and it is very possible that each breed of cattle may present Mendelian factors which behave somewhat differently.

108. Horses and Mendelism.—For the most part, Mendelian studies of the horse have been confined to coat color; but a number of contrasted characters are considered as allelomorphic, in which (1) trotting is dominant to pacing, (2) six lumbar vertebrae, to five, and (3) convex nasal bones, to concave.

To a very large extent, our present comprehensive understanding of coat color inheritance in horses is due to W. S. Anderson ¹¹ of Kentucky; in 14,131 chestnut $\times$ chestnut matings (Table VIII), only 16, or less than .2 per cent, foals of other colors were produced. It is generally recognized that breed record books are in error to the extent of about 2 per cent; and in Anderson's own tabulations of

¹¹ Anderson, W. S., Ken. Research Bul. 180.

410 chestnut matings among saddle horses, 4 bays were reported, but correspondence with the breeders proved them to be chestnut. It is quite evident from these figures that

TABLE VIII
THE INHERITANCE OF COAT COLOR IN HORSES *

Matings		Color of Progeny					
Colors	Number	Chest-nut	Black	Brown	Bay	Gray	Roan
Chestnut×Chestnut	14,131	14,115	10	1	5	0	0
Chestnut×Black...	338	111	83	20	124	0	0
Chestnut×Brown...	253	60	32	31	130	0	0
Chestnut×Bay....	1426	597	56	49	764	0	0
Black×Black.....	326	11	295	15	5	0	0
Black×Brown.....	556	14	198	219	115	0	0
Black×Bay.....	1313	123	295	261	634	0	0
Brown×Brown....	588	13	64	334	157	0	0
Brown×Bay.....	2575	177	132	817	1449	0	0
Bay×Bay.....	3712	474	107	300	2831	0	0
Roan×Chestnut...	38	9	3	2	9	1	14
Roan×Black.....	31	1	11	3	1	0	15
Roan×Brown.....	69	1	5	16	18	1	28
Roan×Bay.....	117	9	5	13	39	1	50
Roan×Gray.....	15	0	0	3	0	5	7
Roan×Roan.....	14	0	0	0	3	2	9
		Not Gray					
Gray×Not Gray...	967	528				439	
Gray×Gray.....	65	18				47	

* Abstract from Kentucky Research Bul. 180, p. 125-127.

chestnut is a recessive color, for the matings of two recessives should always produce a recessive. When chestnut is mated with other colors, such as black, brown, bay, and

roan, some chestnut foals are produced. This is readily accounted for; because an individual exhibiting the dominant factor may, if heterozygous, be carrying the recessive factor as well. Thus, if the dominant-colored individual produces a gamete carrying the recessive factor, chestnut, the resulting offspring will be chestnut, for the chestnut individual can only produce gametes carrying the recessive factor, chestnut. Chestnut varies in shade from a light sorrel to a dark liver color, and of the various chestnuts the light sorrel appears recessive to the darker shades. It also appears that the lighter mane and tail, so frequently found in sorrels, is recessive to the darker colored mane and tail.¹²

Black behaves as a dominant to chestnut, and as a recessive to brown, bay, roan and gray, but the evidence here is not quite so definite; for the 338 chestnut $\times$ black matings gave 20 brown and 124 bay offspring. Large as are these apparent discrepancies, they may be partially accounted for by the fact that a dark brown is frequently called a chestnut, and in the foal it is extremely difficult to state definitely whether it will turn out to be a bay or chestnut and again a brown or a black. Wentworth suggests that bay is black with a dominant restriction factor which confines the black to the mane and tail; supposedly, this restriction factor acts on bay only and thus it may be latently present in chestnut horses. If this quite plausible genetic explanation of bay is accepted, it is then easy to understand how bays might occur from chestnut $\times$ black matings.

Brown is one of the most difficult colors to account for, because it varies in shade from a bay to a black. Anderson is of the opinion that the mahogany-browns should be classified as bay and the seal-browns as black. If this is done and Wentworth's interpretation of bay is accepted, then bay is very plainly dominant to black and chestnut but recessive to roan and gray, for no matings of bay $\times$ bay

¹² Wentworth, E. M., Zeit. Abst. Vererb., 1913.

or bay $\times$ brown, black or chestnut produced roan or gray offspring.

Gray is a color produced by the sprinkling of white hairs in a black coat, and varies in shade from almost white to almost black. A foal is never gray at birth, but is black and becomes gray later on, and in many cases, with age, the black will almost completely disappear. There can be no doubt that gray is dominant to bay and its recessive colors: of 967 gray $\times$ not gray matings, approximately 50 per cent of the offspring were gray; from 65 gray $\times$ gray matings, approximately 75 per cent were gray; and no gray offspring were produced from the various matings of chestnut, black and bay.

Roan in horses, like roan in cattle, is in reality a pattern produced from an admixture of white and colored hairs. It is quite distinctly of three different patterns, viz., strawberry-roan, an admixture of bay and white hairs; blue-roan, an admixture of black and white hairs; and chestnut-roan, an admixture of chestnut and white hairs. Apparently the roan pattern is due to a roan factor working independently of the factor for color, and it is either present or absent in the germ plasm. Its presence is dominant to its absence; hence, when it is present the coat pattern is roan. Like gray, it cannot always be detected in the foals; when young, they appear as bay or black. Once roan is introduced in a strain of horses, it is remarkable for its persistence; but once either it or gray is lost from a strain, they can only be regained by the introduction of new blood carrying their respective factors. The behavior of roan and gray are so similar that Anderson points to the possibility of gray being a form of the black or blue-roan. Roan is plainly dominant to bay, black, and chestnut, but no work has as yet been done to reveal whether it or gray is dominant.

Dun also behaves as dominant to bay, black, and chestnut; but whether it is dominant or recessive to gray and roan is still unknown. Thus Anderson arranges the various

colors in three series with the dominant colors at the top of each series, as in Table IX.

TABLE IX

ARRANGEMENT OF HORSE COAT COLORS ACCORDING TO DOMINANCE

Group I	Group II	Group III
Gray	Roan	Dun
Bay	Bay	Bay
Black	Black	Black
Chestnut	Chestnut	Chestnut

Still another color met with is the white, so common on the face and legs of the Clydesdale and ^{AA}Shire and the white spots of the Indian pony. This is snow-white and apparently an albinoism, for the underlying skin is unpigmented. This condition is like the white face of the Hereford, appearing to be dominant to all other colorations. Its presence is probably due to a dominant restriction factor for color. EE

Color, on first thought, may seem to be of little consequence in horses, but as a matter of fact it is of considerable economic importance. The public in general are willing to pay a premium for certain colors.

Of all colors, the chestnut is the easiest to fix in a strain of horses after having once been introduced; for chestnut $\times$ chestnut produces only chestnut. Chestnut is the standard color in the Suffolk Punch, and in Anderson's investigations covering 12,497 matings, no other color was produced. If the wish is to fix the more dominant colors, then the problem requires a little more persistency, because they may be carrying the latent factors; but if horses of the desired color are continually mated, that color will eventually become fixed, for black has become practically fixed over the recessive red in Aberdeen-Angus cattle.

109. Hogs and Mendelism.—Practically all of our present knowledge concerning Mendelism in hogs is confined to

coat color; it is, however, asserted that the mule-footed (single toe) condition is dominant to the normal condition. By various matings of the red Duroc-Jersey, the white Chester-White, the black Berkshire and Poland-China, and the black but white-belted Hampshire, Lloyd-Jones and Evvard¹³ obtained results which are summarized in Table X.

TABLE X
RESULTS OF MATING HOGS OF VARIOUS COLORS

Matings	Colored Progeny
Homozygous Hampshire×White breeds...	Blue-roan with white belt
Homozygous Hampshire×Red breeds.....	Black <i>Belt ?</i>
White breeds×Poland-China or Berkshire.	White or white with black spots
Red breeds×Berkshire or Poland-China...	Red with black spots

White is plainly dominant to both red and black, except the black of the Hampshire. The Hampshire black is evidently a different and stronger black than that of the Poland-China and Berkshire. In most cases, the purebred Hampshire is homozygous for the black factor, but not always so; for occasionally, but very rarely, reds do appear among purebred Hampshires. The white belt of the Hampshire, like the Hereford's white face and the Clydesdale's white face and legs, is apparently dominant to all other coloration, and doubtless a dominant restriction factor is responsible for this. The Berkshire and Poland-China breeds are black with white extremities. In this case, the white is also probably due to a dominant restriction factor.

As indicated in Table X, the Berkshire or Poland-China crossed on red breeds produced, for the most part, pigs that were red with black spots. Quite similarly, when a Hampshire boar, which was heterozygous for black, was mated to red sows, red pigs with black spots were obtained. It

¹³ Lloyd-Jones and Evvard, Iowa Research Bul. 53.

would seem from this that red and black are not always simple allelomorphs. On the other hand, red occasionally appears among Berkshire pigs—red stock contributed to the foundation and a red breed of Berkshires exists in the Southern states at the present time—all of which would indicate that in the Berkshire, at least, black was dominant to red; it would not, however, necessarily be a simple dominant, for more than one pair of contrasted factors might be involved.

110. Sheep and Mendelism.—Very few exact Mendelian data are available in connection with sheep. It is stated that the short-eared is dominant to the long-eared character. It is evident that the black-wooled character is recessive to the white-wooled character (Fig. 23). If white and black fleece are simple contrasted characters, it is then extremely difficult to account for the far too common scattering of black fibers throughout the fleece of some breeds of sheep. It may be that this latter condition is due to a pattern factor, as is the roan character in horses; but, whatever it is, it upsets the supposition that black and white fleece are simple allelomorphs.

The inheritance of horns in sheep has been subjected to Mendelian studies and is found to be linked with sex inheritance. In the Dorset Horn, both sexes are horned; in the Rambouillet and Merino, only the males are horned; and in the Down breeds, both sexes are selected for the hornless character but rudimentary horns occasionally appear in the rams. Wood ¹⁴ crossed Dorset Horns and Suffolks, and the F_1 rams were all horned while the ewes were hornless. The F_2 generation contained horned and hornless individuals among both sexes in the approximate ratio of: rams, 3 horned: 1 polled; ewes, 3 polled: 1 horned. The assumption is that the horned character is dominant in the ram; therefore, one H factor is sufficient to develop horns in the ram; but that the horned character is recessive in the female.

¹⁴ Reported by Punnett, R. C., *Mendelism*, p. 72.

In other words, the ram may be heterozygous for the horned condition and develop horns, while the female must be homozygous for the horned condition before she can develop horns. Thus, chance matings of large numbers

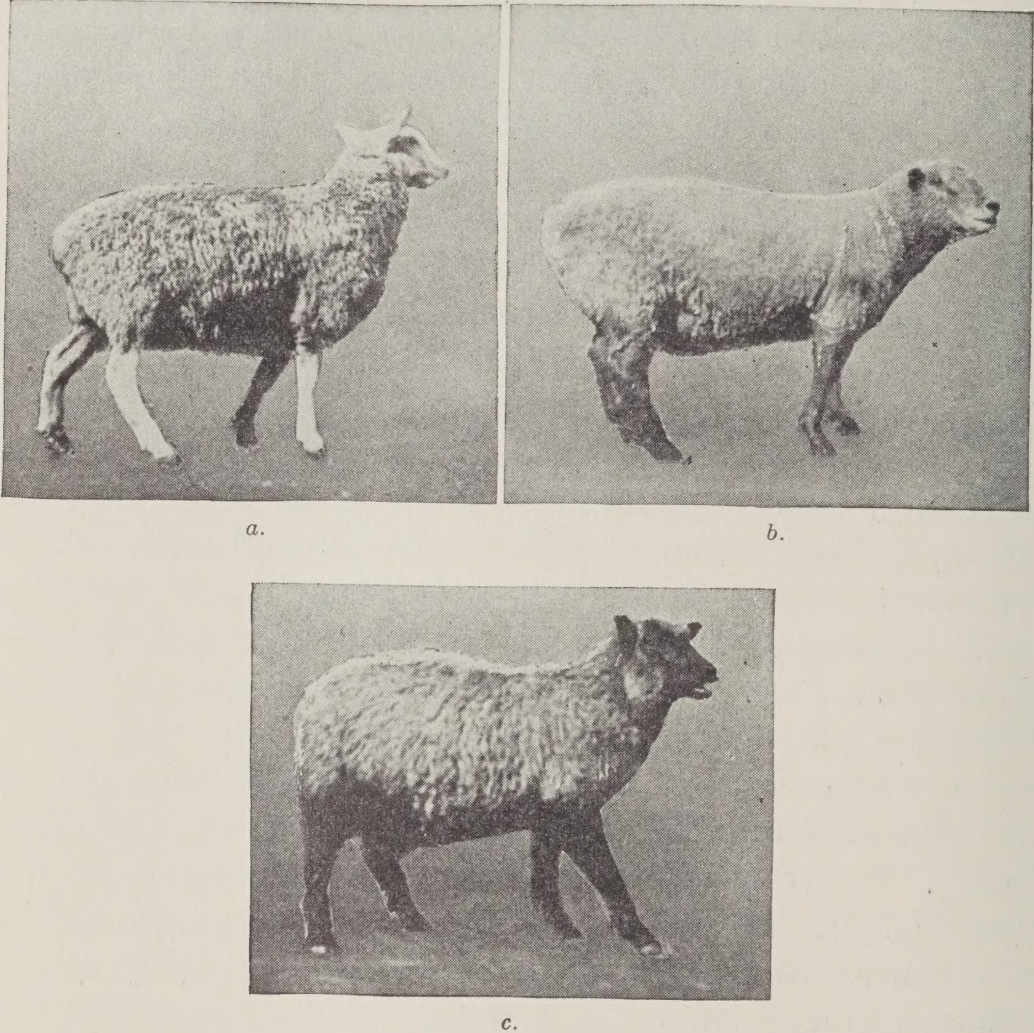


FIG. 23.—Black-wooled character apparently is recessive to white-wooled character.

a, A purebred Leicester ewe, mated to *b*, a purebred Southdown ram, dropped *c*, an individual with black face, ears and legs and having a brownish-gray fleece, in the flock of the University of Saskatchewan.

would produce the proportions indicated above for the F_2 generation.

It should not, however, be assumed that a hornless breed of sheep has necessarily lost the horned character entirely.

The writer has found quite pronounced rudimentary horns, not only in Suffolk rams, but in Suffolk ewes as well. All of the Down breeds of sheep are hornless in both sexes; yet horned blood was used in building their foundation, and it is not at all uncommon to find rudimentary horns appearing in the rams of these breeds, although they never appear as fully developed horns. Castle¹⁵ explains this as being due to the fact that the horned character has fallen so low in potency that under ordinary conditions no visible horns are produced.

111. Poultry and Mendelism.—Poultry furnish a fertile field, among domestic animals, for the study of Mendelism, because of their relative ease of reproduction and their comparatively low cost. In consequence, a large number of contrasted characters have been discovered (Table XI).

In reviewing the list, it should be distinctly borne in mind that the characters listed are not necessarily sharply contrasted characters, but that much more concerning them may be disclosed by further experimental study. It does, however, give a rather vivid view of the many and varied character contrasts that may be found with further study of our domestic animals.

112. Possibilities of Mendelism.—It must be admitted that the various characters of our domestic animals, which have up to date been shown to follow the Mendelian plan of inheritance, are of more importance from a genetic standpoint than an economic one. Yet, it is only by first gaining a good understanding of these more simple characters and their genetic behavior that a Mendelian understanding of the apparently more complicated economic characters, e.g., deep flesh, endurance, heavy milking, etc., can be obtained. It is very likely that further study will show that many characters, which at first appear to be simple allelomorphs, in reality involve many factors; e.g., at first glance it would appear as though eye color would involve only simple

¹⁵ Castle, W. E., *Heredity*, p. 103.

allelomorphs, yet Morgan ¹⁶ has shown that at least twenty-five factors are known to be involved with eye color in *Drosophila*.

TABLE XI
BEHAVIOR OF CONTRASTED CHARACTERS IN FOWL *

Dominant	Recessive	Expression
Barred plumage pattern.	Uniform coloration	Sex-linked
High fecundity.....	Low fecundity....	Sex-linked
High fecundity.....	Low fecundity....	Non-sex-linked
Beard.....	No beard.....	Almost completely dominant
Black.....	Red, buff.....	Almost completely dominant
Black.....	White (Minorca)..	Almost completely dominant
Buff.....	White (Minorca)..	Almost completely dominant
Broodiness.....	Non-broodiness....	Almost completely dominant
Rapid feathering.....	Slow feathering...	Almost completely dominant
Red.....	White (Minorca)..	Almost completely dominant
White.....	Colored plumage..	Almost completely dominant
Brown striped down....	Pale brown down..	Completely dominant
Dark shank color.....	Light shank color..	Completely dominant
Frizzle feathering.....	Normal repent feathering	Completely dominant
Rose comb.....	Single comb.....	Completely dominant
Single comb.....	Comblessness.....	Completely dominant
Walnut comb.....	Pear, rose comb...	Completely dominant

* Except for the omission of characters disputed by Punnett and the imperfectly dominant characters, and for a regrouping, the table is essentially the same as that presented by Babcock and Clauson, "Genetics in Relation to Agriculture," p. 477.

The possible economic advantages to be gained, by a more complete knowledge of Mendelism in our domestic animals, are numerous; it is quite evident that Aberdeen-Angus cattle obtained their color from the old Celtic cattle, and their size and ease of fattening from the English Long-horn, while the polled condition and possibly their short legs and high-testing milk were inherited from the Scan-

¹⁶ Babcock and Clauson, Genetics in Relation to Agriculture, p. 194.

dinavian cattle.¹⁷ It is also quite credible that the American Saddle Horse inherited his style, grace of carriage, and beauty of head and neck from his Oriental ancestors, while his stature and slender frame were probably inherited from the Thoroughbred. (The Oriental also contributed to the Thoroughbred's origin.)

It should not be inferred, however, that in the development of a new breed by crossbreeding, the new breed will inherit various ancestral characters intact; and undoubtedly, in the above-mentioned cases, some modification of the ancestral characters took place. For example, it is unlikely that the Aberdeen-Angus breed obtained their size and ease of fattening from the English Longhorn unmodified—very probably there was a beneficial modification—and it is equally doubtful if the American Saddle Horse inherited his style, grace of carriage, and beauty of head and neck unmodified. The Holstein-Friesian breed of cattle undoubtedly obtained their white color from a strain of pure white cattle brought to the district of Friesland from India about 300 B. C., and their black color from a strain of pure black cattle brought to the same district about 100 B. C. by a tribe of wanderers called Batesians. Galton speaks of this as “particulate inheritance,” but nevertheless it is an example of the operation of Mendelism, in which neither the black nor the white color is transmitted as a unit. Walter¹⁸ suggests that this is due to the absence of the factor for uniformity.

On the other hand, too much should not be expected of Mendelism. Desirable as it might be to combine speed and power, yet it is quite evident that a maximum of both cannot be obtained in the same horse. Likewise, a great deal of interest has been manifest in the breeding of dual-purpose cattle, which involves the combining of high milk and butterfat yields with the production of a high-grade

¹⁷ Wilson, James, *The Evolution of British Cattle*.

¹⁸ Walter, *Genetics*, p. 164.

carcass. While great progress has been made in this direction, it can scarcely be expected that a maximum of both will ever be obtained in the same animal. The obstacle in both the above cases is that these economic qualities involve various morphological, physiological, and psychological characters, which are correlated with the desirable economic characters, and these correlations are extremely difficult, if not impossible, of dissolution.

If it is desired to develop a new breed which will combine the valuable qualities of two or more breeds, it can only be done by crossbreeding, followed by continued diligent selection for individuals possessing the desired characters. At the present time, livestock husbandry has a far greater need for improvement of the rank and file of our existing breeds, and for a more widespread use and appreciation of them, than for additional breeds.

Undoubtedly, however, the next decade or two will witness great progress in connection with Mendelian inheritance in our domestic stock, and it is a question that deserves the most careful consideration.

2. BLENDING INHERITANCE

113. Many Characters Blend.—Not all inheritance is of the simple Mendelian type, in which one of a pair of contrasted characters is dominant; many characters in the offspring represent a blend of the parental differences in this regard. It should, however, be distinctly borne in mind that this type of inheritance is not necessarily contrary to Mendelism, but that under certain conditions, the original Mendelian theory may require certain elaborations.

114. Galton.—Francis Galton, cousin of Darwin, an eminent English biologist and a contemporary of Weismann, first drew attention to this type of inheritance. Galton's studies ¹⁹ were of the inheritance of stature in the

¹⁹ Galton, Francis, *Natural Inheritance*.

English people, and some very important conclusions were reached. In his studies of stature the question arose, "Will children of parents 70 and 62 inches respectively (average 66) be the same height as those of parents each of whom is 66 inches in height?" After studying many cases, Galton found no difference, and concluded that, in respect to stature, a blend takes place.

115. Blending Inheritance in Rabbits.—In recent years, Castle ²⁰ has corroborated this conclusion; when a large rabbit was crossed with a small one, the young were intermediate in size, representing a true blend, and the F_2 offspring showed no tendency to segregate into groups of large, small, and intermediate-sized individuals. The skulls of the offspring also showed an absolute blend of both dimensions and proportions, and the blend was possessed by the F_2 generation. The original female possessed long, lop ears, while the original male had short, erect ears; the offspring, however, were intermediate both in respect to length and the lop of the ears.

The fact that offspring represent a blend in some characters does not necessitate their blending in all respects. The above-mentioned rabbits, while showing a blend regarding size of skull and body, and length and lop of ears, manifested dominance and segregation in respect to coat color and length of hair. The father, which was short and erect-eared and small of skull and stature, was an albino and long-haired. The mother, which was long and lop-eared and large of skull and body, was of a sooty-yellow color and short-haired. The son was intermediate regarding size of both skull and body, intermediate regarding lop and length of ear, and was black and short-coated, the father's albinism and long coat behaving as recessives, as they should in accordance with Mendelism. The son, however, showed an intensification of pigmentation, which may be explained by the black having been received through the albino parent

²⁰ Castle, W. E., The Carnegie Institution of Washington, 114.

as a latent factor and becoming active in the son. (Certain factors may lie dormant for generations and only become visible through the presence of some other factor or factors; in the above case, possibly through the factor for sooty-yellow obtained from the mother.) The recessive albinism was entirely excluded from the F_1 generation, 7 in number, but re-appeared in 1 F_2 individual, although size of skull and body and the lop and length of ear continued to behave as intermediates in all the F_2 individuals.

The explanation of the above is that *dominance* is lacking and that *segregation* was not evinced because of the large number of factors involved; this is known as the *multiple factor hypothesis*. That dominance is lacking in certain cases, but yet that segregation does occur in subsequent generations, has been demonstrated in various other experiments, where the number of factors involved apparently was decidedly less than in the above-mentioned case. As the number of factors involved increases, the chances of recovering the original parental types becomes decidedly reduced; for instance, when three independent factors are involved, the chances of recovering either of the grand-parental types in the F_2 generation is 1 in 62; while if four pair are involved, the chances are reduced to 1 in 256; and if six are involved, they are reduced to only 1 in 4096. One can, therefore, appreciate how extremely difficult it is to demonstrate segregation when many multiple factors are involved.

116. Galton's Studies Involved 928 Adult Children and 410 Parents.—Having satisfied himself that mid-parental height was a safe basis for hereditary studies, Galton proceeded to make allowance for sex differences by transforming the heights of the mother and daughter to the heights of the father and son. He found that English women were, on the average, one-twelfth shorter than men; therefore, by multiplying the heights of the mother and daughters by 1.08 respectively, he recorded them in terms of male values.

Mid-parental height was obtained by multiplying the height of the mother by 1.08, adding the result to the height of the father, and dividing by 2. By grouping the parents of various heights, e.g., those from 70 to 71 inches in height constituting one group, it was possible to compare them with the heights of their children and as to the height of children produced; and by grouping the children of various heights, e.g., those from 65.7 to 66.7 inches in height constituting one group, it was possible to compare them with the heights of their parents and as to the height of parents from which they were produced. In general, there was a tendency for the offspring to resemble the parents: there was a tendency for the tall parents to produce tall offspring, and for the short parents to produce short offspring; likewise, there was a tendency for the tall offspring to be produced by tall parents, and short offspring by short parents.

Interpreting the above results in livestock terms and accepting arbitrary values, it would mean that a breeder, by mating ton horses, would stand one chance out of two of getting ton horses, while if mating 1600-pound horses he would stand only one chance out of eight of getting ton horses. If evolution by loss or inferiority is the aim, it will be found to work out in practically the same way as aiming for superiority; that is, the largest number of inferior offspring will be produced by parents superior to the offspring, but proportionately the inferior parents will produce a greater number of inferior offspring. Therefore, by continued selection for either superiority or inferiority, the probability of producing either one may be greatly increased.

On the other hand, there was a limited similarity between any specific group of parents and their offspring: like parents produced unlike offspring and like offspring were produced from unlike parents.

117. Regression.—The work, therefore, demonstrated that the saying, "like begets like" is only partially true. It revealed that there was a strong tendency for offspring

of extreme parents to revert to the average of the race, i.e., for the tall parents to produce offspring shorter than themselves, and for the short parents to produce offspring taller than themselves. This tendency is termed regression.

The reason for regression is that offspring do not inherit their tendencies from their immediate parents only, but also from their entire ancestry; thus, the ancestors beyond the immediate ones constitute a "pull," or "drag," which is spoken of as the "drag of the race." Therefore, the superior parents (regarding increased height as superior) tend to produce offspring that are inferior to themselves, while the inferior parents (regarding decreased height as inferior) tend to produce offspring superior to themselves.

Disadvantageous as regression is in the former case—since livestock breeders are practically always trying to breed something on rather than off, e.g., increased milk flow, full hindquarters, etc.—it has some compensation in the latter case. The only remedy for regression is continued selection for the positive characters. This eventually causes them to become more fixed, but possibly seldom if ever absolutely fixed.

118. Progression.—While it is true that the majority of the offspring will tend to revert to the racial average, yet some individuals are superior to their parents. This is progression. The livestock breeder is looking for progression; he is, in the main, attempting positive breeding (adding new characters or supplementing those already present) rather than negative breeding; but evolution by loss may be as useful to him as evolution by gain.

119. The Law of Ancestral Heredity.—Since the individual's inheritance is from the ancestry as a whole rather than from the immediate parents, those characters in the individual which are the result of a blend are not merely the result of a blend of the characters possessed by the immediate parents, but they are the result of a blend of the characters possessed by the entire ancestry. In the selec-

tion of breeding animals, the question arises, "Just how much will the various ancestral generations and individuals of these generations, parents, grandparents, great-grandparents, etc., contribute to this individual's breeding ability?" In answer to this question, and as the result of the aforementioned study of stature in English people, corroborated by studies of color inheritance in dogs, Galton formed what has become known as Galton's Law of Ancestral Heredity, which is one of the greatest, if not the greatest of the practical contributions of biology to animal breeding, and which is presented in Table XII with an additional column showing the effective hereditary contribution of each ancestor.

TABLE XII
GALTON'S LAW OF ANCESTRAL HEREDITY

Generations Backward	Number of Ancestors	Effective Contribution of Each Generation	Effective Contribution of Each Ancestor
1	2	$\frac{1}{2}$	$\frac{1}{4}$
2	4	$\frac{1}{4}$	$\frac{1}{16}$
3	8	$\frac{1}{8}$	$\frac{1}{64}$
4	16	$\frac{1}{16}$	$\frac{1}{256}$
5	32	$\frac{1}{32}$	$\frac{1}{1024}$
6	64	$\frac{1}{64}$	$\frac{1}{4096}$

The above table can be reproduced with ease if the first row is committed to memory. To get each successive row, multiply each preceding figure in the second column by 2, each one in the third column by $\frac{1}{2}$, and each one in the fourth column by $\frac{1}{4}$.

The table illustrates very vividly that an individual cannot be cut off from its ancestors, and that, even though the number of generations be carried back to infinity, an ancestor of that generation would be making a slight contribution to an individual's constitution. It also shows that the immediate ancestors contribute by far the greater share to

an individual's genetic composition; therefore, in selection, they should receive the greater consideration. Galton's Law of Ancestral Heredity serves as a working basis for the emphasis a breeder should lay upon the various individuals mentioned in an animal's pedigree.

120. Blending Inheritance and Animal Breeding.—It would seem from observation that the greater number of the economic characters sought for by breeders, such as size, deep flesh, heavy milk and butterfat production, etc., are the result of a blend of characters rather than of simple dominance. If a draft stallion, weighing a ton, is used on a general-purpose mare, weighing 1250 pounds, the resulting progeny represents very much of a blend, so far as size, draftiness, and type are concerned. If a low-down, thick, beefy bull is used on rather common long-legged cows, the offspring are also very much of a blend so far as the economic characters, viz., deep flesh, short legs, and depth and width of body, are concerned. In a like manner it is quite evident that milk and butterfat production are the result of a blend of characters as transmitted by the parents.

It is also very evident that the economic characters mentioned above are in each case developed from an infinitesimal number of factors in which dominance is probably lacking, and that therefore they, in the progeny, are the result not of their parents' phenotype but of their genotype—the ancestry as a whole. This, however, does not mean that Mendelism is of no significance in animal breeding, but that it is more than likely in the larger number of economic characters, that dominance is lacking and that each character is the outgrowth of a large number of factors. It is therefore more than likely that many, even a majority, never will be differentiated.

On the other hand, it is very likely that a close study of many individuals, carried on over a period of years, would reveal many more characters in which dominance is present, many of which might even be of economic importance in

themselves. The writer's very limited study of crossbred sheep (Southdown-Leicester) would indicate that diameter of fiber is transmitted as a blend; crimps per fiber as a blend; and that a long staple is dominant or partially dominant to a short staple. This study covers only six crossbred sheep, wethers and ewes, and their parents, and Table XIII is presented not because of its conclusiveness but because of the suggestions it offers as to future study. Sample fibers were taken, in each case, from the shoulder, side, and hip, and the figures presented in the table are the average of the total number of measurements. The measurements were taken during midwinter, rather than at shearing time. The reason for this was that it was necessary to dispose of some of the individuals.

TABLE XIII

THE INHERITANCE OF FLEECE IN CROSSBRED SHEEP

Group	Diameter of Fiber in $\frac{1}{1000}$ inch	Crimps per Fiber	Length of Staple in Inches
Purebred Southdown.....	0.9	14.33	1.33
Purebred Leicester.....	1.19	2.08	6.67
Average.....	1.045	8.205	4.00
Crossbred.....	1.0	6.83	6.58

The above at least suggests what might be revealed by detailed studies along this line. A detailed study of the inheritance of such unsoundnesses as stringhalt, roaring, etc., might reveal much of economic importance. Much might also be learned regarding the inheritance of set of legs and feet, by a detailed study. The difficulty with such studies is that to be conclusive they must cover large numbers and many generations; and livestock is relatively slow of reproduction and very expensive as compared with laboratory animals and many plants.

3. PREPOTENT INHERITANCE

121. Prepotency Defined.—Both parents are not of equal power in their ability to transmit characters to their offspring, and this superior power of one parent over the other, in determining the character of the offspring, is called prepotency. A type of inheritance frequently spoken of as exclusive inheritance, in which the characters of one parent appear to the exclusion of those of the other is in reality prepotency, and is due to the greater prepotency of one of the parents.

Prepotency is of two kinds, racial and individual. Individual prepotency manifests itself in the mating of two individuals of the same breed or race, while racial prepotency may manifest itself in crossbreeding, the mating of two individuals of different breeds or species.

122. Factors Determining Prepotency.—The various factors which make for prepotency are: (1) a long line of pure breeding, (2) intensification of the hereditary force as the result of closebreeding (Chapter XII), (3) individual inherent character, and (4) dominance.

Number 1 is a cause of racial prepotency; the race or breed that has been bred pure for a long time is the prepotent one; certain breeds and races are more prepotent than others. In hogs, the Yorkshire is a good example of a long line of pure breeding, and likewise a good example of a prepotent race. In sheep, the Merino is a good example of breed prepotency, and its history is an old one, going back to the beginning of the Christian Era. As a contrast, it would not be expected that the Corriedale sheep, a breed of very recent origin, would be so prepotent as the Merino. The greater prepotency of the purebred over the scrub, which is very evident, is still another example of this type of prepotency. The individual or breed with a long line of pure breeding is the one that is more nearly homozygous.

Factor number 2 furnishes a cause for greater prepotency, either of the breed or of the individual. A breed or an individual that has been closebred to a great extent can be expected to be more prepotent than one not closebred. Closebreeding makes for prepotency, because it intensifies the hereditary force by the doubling up of that force for certain characters (175). The individual becomes homozygous for many characters.

Factor number 3 has strict regard to individual prepotency. Full brothers or full sisters may vary widely in their prepotent powers. When the breeder selects breeding animals he is always hoping that they will possess individual prepotency.

Factor number 4 again offers an opportunity for greater prepotency either of individual or breed; it is very evident that the individual or breed possessing the larger number of dominant factors will be the prepotent one.

123. Additional Suggested Influences on Prepotency.—

It has frequently been suggested that such factors as sex, age, constitutional vigor, and development may influence prepotency.

The belief is quite general that the sire is more prepotent than the dam. Common observation would indicate that such is the case; for ordinarily, a breeder uses a stronger breeding male than the average of his females. This would be especially true in grade herds where the sire is a purebred and the females are grades. Various characters have been proven to be connected with sex; e.g., in chickens, a heavy-laying hen does not impart her high fecundity to her daughters, but to her sons, who impart it to their daughters. This, however, is a matter of sex-linkage, and as yet nothing has been presented which would indicate that, in mammals, one sex is more prepotent than the other.

It is, likewise, rather generally believed that age has an influence on prepotency, i.e., that a young sire will not prove so prepotent as he will be later on in his life. Studies by

Allen ²¹ would, however, indicate that age has no influence upon prepotency.

It is frequently held that strong, robust individuals are more prepotent than those lacking constitutional strength; if this were true, it would prove very beneficial, for it would make improvement of the race easy and quite general; offspring would always more nearly resemble the stronger of their parents, which would make for improvement. But, here again, proof is lacking.

That development aids prepotency is another belief; e.g., that a speed stallion will sire faster offspring after having had his own speed developed than before it was developed. It is quite likely that this belief arose from the fact that after a stallion lowers his record, faster mares will be brought to him, and thus he will have a better chance to sire fast stock. In the above three rather common beliefs regarding influences or prepotency, there is no rigid experimental proof one way or the other; but, in the light of present-day knowledge concerning inheritance by means of the chromosomes, it is extremely difficult to understand how any of these suggested factors might affect prepotency.

124. Importance of Prepotency.—Prepotency is of great importance to the livestock breeder because of its influence on improvement. If a sire of superior individuality, after being purchased by a breeder at a long price, is able to impress his individuality upon the offspring, improvement has been made; if he fails to get offspring approaching his own likeness, no improvement has been made and even degeneration may have resulted.

Many examples of prepotency may be found among the leading breeds of livestock. A few of the outstanding illustrations will be discussed in the subsequent paragraphs.

125. Prepotency in Holstein-Friesians.—Many good examples of prepotency are to be found among all breeds of dairy cattle, not that they are more prepotent than other

²¹ Allen, C. L., *Holstein-Friesian World*, April 28, 1923.

breeds of livestock, but because their records of performance, like those of speed horses, lend themselves to more accurate tabulations than the performance of either block animals or draft horses.

Holstein-Friesian cows up to 1921, with records the equivalent of 800 pounds or over of butterfat (allowance having been made for heifers at the rate of .1 pound of butterfat for each day under five years at the time of freshening) were sired by 285 different sires.²² While 285 sires were necessary to sire the total of 465 cows, an average of 1.6 each, yet the leading 10 (Table XIV) sired 103, 24 per cent of the total, an average of over 10 each. The leading sire, King of the Pontiacs, however, sired 20. He has approximately 13 times as many 800-pound daughters as the average of the 285 sires. It must also be kept in mind that these 285 are selected sires, for any sire of an 800-pound cow is far above the average of the breed.

A review of Table XIV will reveal that, in the main, these 10 leading sires of 800-pound butterfat daughters are not only prepotent as sires but as grandsires as well; the records of Piebe Laura Ollie Homestead King, Spring Farm King Pontiac 6th, and King Segis Pontiac Count will undoubtedly improve in this regard, for they were not dropped until 1911. The interesting point in this connection, however, is that, with but 3 exceptions, the 285 sires trace direct to but 4 sources, namely, Mechthilde Sir Henry of Maplewood, De Kol 2ds Prince, Netherland Prince, and Admiral Walker. And still more interesting is the fact that the vast majority of the 285 trace to the famous old Holstein-Friesian cow, De Kol II. She, in 1894, took first prize in New York for butter production, producing 26,516 pounds of milk from three quarters, at an age of 10 years and 11 months; and the claim is made that, with but one exception, she appears in the pedigree of every 40-pound cow of the breed.

²² Hunt, R. E., *Holstein-Friesian World*, May 7, 1921.

TABLE XIV

TEN LEADING SIRES OF THE EQUIVALENT OF 800-POUND BUTTERFAT
DAUGHTERS

Rank	Name of Sire	Number Equivalent to 800- Pound Daughters	Number Daughters With Tested Daughters	Proven Sons
1	King of the Pontiacs.....	20	100	194
2	Sir Pietertje Ormsby Mercedes.....	17	20	29
3	King Segis Pontiac Count.....	13	12	11
4	King Pontiac Champion.....	11	35	36
5	Ormsby Korndyke Lad.....	11	9	6
6	Pontiac Aaggie Korndyke.....	9	24	25
7	Sir Johanna Piebe.....	6	14	10
8	Spring Farm King Pontiac 6th.....	6		10
9	King Walker.....	5	29	32
10	Piebe Laura Ollie Homestead King..	5	2	2
	Total.....	103	245	255

Another interesting instance of prepotency among Holstein-Friesians is to be found in Aaggie Cornucopia Paul 2d. She has four 1000-pound butter daughters, one of which is the dam of a 1000-pound daughter, which in turn is the dam of a 1000-pound daughter. Table XV presents the genealogy of this remarkable group of females.

TABLE XV

GENEALOGY CHART OF A REMARKABLE HOLSTEIN-FRIESIAN FAMILY

Aaggie Cornucopia Paul 2d (28.6 % B. 7 days)

1. Aaggie Cornucopia Colantha (1136.51 % B.)
 Aaggie Princess of Sunny Side (1100 % B.)
 Aaggie Belle of Sunny Side (1048.88 % B.)
2. Aaggie Marie of Sunny Side (1101.33 % B.)
3. Aaggie Queen of Sunny Side (1067.33 % B.)
4. Aaggie Cornucopia of Sunny Side (1093.46 % B.)

126. Prepotency in Beef Cattle.—The show ring is to block animals and draft horses what production records are to the dairy cow and speed records are to the race horse. The results, however, are not so exact, for show ring honors are comparative, dependent upon the strength of outside competition.

In a study made by the writer, of North America's 444 most prominent Shorthorn show animals for 1920, it was found that 176, approximately 40 per cent, traced direct to Whitehall Sultan; 92, or over one-half, coming through his son, Avondale. In the same study, a rating of the 25 leading sires of Shorthorn show animals was made, and of the 25, 9 traced direct to Whitehall Sultan. Whitehall Sultan and Avondale do not go back very far in Shorthorn history, and this plainly shows the remarkable affect they are having upon the breeding of American Shorthorns.

The writer made a similar study of Hereford show winners for 1919, in which the 1137 most prominent entrants were traced to their original source on the sire's side. Of the 1137, 798 traced direct to Anxiety 4th; 324 to Sir Roger, 319 of which came through Garfield; 10 to Adonis; and 5 to The Grove 3d. The remarkable effect of the two bulls, Anxiety 4th and Garfield, upon present-day Herefords is thus emphasized. Both of these bulls were extraordinary individuals for their day, and by the aid of selection, on man's part, they have been able to "breed on and on."

No similar studies among Aberdeen-Angus have come to the writer's attention, but it is beyond question that a study of this kind would reveal similar examples of prepotency. The great influence that the bulls, Old Jock, Panmure, Black Prince of Tillyfour, and Trojan, and the matrons, Erica, Lady Ida and her daughter, Blackbird of Corskie, and Queen Mother and her great-granddaughter, Pride of Aberdeen, have had on the breed, is common knowledge among those familiar with Aberdeen-Angus breeding.

127. Individuality and Prepotency.—It was mentioned in the above that Garfield and Anxiety 4th were remarkable individuals. In the same study of Herefords mentioned above, a rating was made of the leading sires of show animals for that year. Of the 25 leading sires, 8 were first-prize International animals themselves. (It is practically



FIG. 24.—Rodney, got by a show bull, a show bull himself and a sire of show stock, an illustration of prepotency. (*Courtesy Carpenter & Ross.*)

certain that Woodford, one of the 25, would have won similar honors had the International been held in 1914 and 1915, and that would have made 9.) Thirteen were sired by first-prize International bulls; 17 either won the honor themselves or their sires achieved it; while 18 were grandsired by first-prize International bulls.

The pedigrees of the 25 bulls were tabulated in the extended form to the fifth generation, and of the 775 total

bull places, 243, nearly 1 out of 3, were filled by bulls that had been first in class at the International or had achieved a corresponding honor before the time of the International.

In the Shorthorn study mentioned above, a like rating was made of the leading sires of 1920 show stock. Rodney (Fig. 24), sired by the British show bull, Sanguhar Dreadnaught, a show bull himself, headed the list of sires.

128. Prepotency in Percherons.—Among the Percherons, Brilliant 3d and his grandsire, Brilliant 1271, are good illustrations of prepotency, as will be seen by the following studies of the breed.

A study of the winning horses at the Perche Percheron show, from 1901 to 1910 inclusive, disclosed that 1418 horses were awarded prizes in the individual classes.²³ On tabulation of their pedigrees, it was found that 476 stallions appeared only once as great-grandsires of the winners; they and their descendants were eliminated. The 942 remaining animals traced to but 80 different great-grandsires, the 8 leaders of which appear in Table XVI.

TABLE XVI

LEADING GREAT-GRANDSIRE OF PRIZE WINNING PERCHERONS IN FRANCE
FROM 1901-1910

Rank	Great-Grandsire	Appeared
1	Brilliant 3d.	123
2	Besigue.	92
3	Villers.	87
4	Fénelon.	71
5	Voltaire.	61
6	Jules.	50
7	Marathon.	38
8	Briard.	30

Of the 80 great-grandsires considered, 46, or 57 per cent, were of Brilliant breeding; while of the 942 individuals

²³ Sanders and Dinsmore, A History of the Percheron Horse, Chap. XV.

considered, 724, or 76.8 per cent, carried Brilliant breeding. The 8 ranking progenitors contributed 58 per cent of the 942 prize winners considered, and all of the 8 were of Brilliant breeding. A genealogy of the 8 ranking stallions is shown in Table XVII; the numbers in parentheses indicate their rank.

TABLE XVII

GENEALOGY OF THE EIGHT RANKING GREAT-GRANDSIRE OF PRIZE WINNERS
IN FRANCE FROM 1901-1910

Brilliant 1271—	{	Fénelon (4)—Brilliant 3d (1)—Besigue (2)
		Briard (8)—Villers (3)—Jules (6)
		Voltaire (5)—Marathon (7)

In a similar study of the breeding of International prize winners from 1900 to 1910 by the same authors, the ranking sire, Calypso, was by the ranking grandsire, Theudis, he by the ranking great-grandsire, Besigue, and he in turn was by Brilliant 3d, the ranking great-grandsire of French show winners from 1901-1910. In discussing certain dominating strains in the Percheron breed, which are really due to the outstanding characteristics of some one or several individuals, Dinsmore contributed the following:²⁴

“There are certain dominating strains in the Percheron breed although less attention has been paid to blood lines than to individual merit. The leading strain is the Brilliant and this family may be said to rest on the two horses, Brilliant 3d and his grandsire, Brilliant 1271. Brilliant 3d, in the judgment of experienced Percheron breeders, is the sire of greatest influence used within the past thirty years. This is because of the large number of noted sires and dams begotten by him.

“Practically coordinate with Brilliant 3d in influence is his grandsire, Brilliant 1271, at the head of the Dunham stud at Wayne, Illinois, from 1881 until death in 1896.”

²⁴ Dinsmore, Wayne, *The Breeder's Gazette*, June 25, 1914.

129. Prepotency in Other Draft Breeds.—A systematic study of prepotency in Belgians would without doubt reveal the predominating influence that Orange 1st and his son, Jupiter, have had on the breed.

While the writer has not made a systematic prepotency study of the Clydesdale breed, yet he has tabulated a large number of pedigrees of the most famous Clydesdale show animals and sires of show animals, of both North America and Scotland, and without an exception, they all traced directly to either Darnley or the Prince of Wales. These two old stallions left such outstanding offspring that to-day their descendants have practically replaced all other lines of breeding.

In a prepotency study ²⁵ of the 2218 Shires awarded prizes at the London Shire Show for a period of twenty years, ending in 1912, it was found that 1257 or 67 per cent, traced directly to Lincolnshire Lad II; 440, or 20 per cent, traced to William the Conqueror; 235, or 10 per cent, traced to Matchless; the remainder, 286, or 3 per cent, traced to mixed sources.

130. Prepotency in Standardbreds.—One of the most exhaustive studies of prepotency ever made was a study by Davenport ²⁶ of the transmission of speed in harness horses. The studies covered all horses that had been registered and that had made track or breeding records from the opening of the Register and the Yearbook down to and including 1901. Up to that time, 26,327 individuals had made 2:30 records. These 26,327 were sired by 6278 sires; but of these 6278 sires of speed, only 207 had produced 10 or more sires or dams of speed. These 207 sired 5377 performers, which was 20 per cent of the total number of performers.

Of these 207, only 85 were the sires of 10 or more sires of speed and 10 or more dams of speed; in addition, however, these 85 sired 3746 performers, 14 per cent of the total.

²⁵ McFarland, Ellis, The Breeder's Gazette, June 11, 1914.

²⁶ Davenport, E., Principles of Breeding, Chap. XV.

From these 85, the "Big Ten"—the 10 leading sires of speed—were selected. The "Big Ten" produced a total of 1311 performers, an average of 131 each, which is 32 times the number produced by the average sire and nearly 5 times the number produced by the average of the 207.

The remarkable point in connection with the "Big Ten" is that 1 was sired by Belmont, a grandson of Hambletonian 10; 1 by Happy Medium, and 7 by George Wilkes, both sons of Hambletonian 10; while 1 was sired by Hambletonian 10 himself. Table XVIII presents the genealogy of the "Big Ten"; the figures in parentheses indicate the individual's total number of performing offspring.

TABLE XVIII

GENEALOGY CHART OF THE TEN LEADING SIRES OF SPEED UP TO AND INCLUDING 1901 *

Hambletonian 10—	{	Abdallah—Belmont—Nutwood (165)	
		Happy Medium—Pilot Medium (114)	
		George Wilkes—	
		{	Onward (158)
			Red Wilkes (157)
			Alcantara (149)
			Simmons (105)
			Wilton (103)
			Gambetta Wilkes (101)
			Baron Wilkes (99)
	Electioneer (160)		

* Made up from Davenport, E., Principles of Breeding, p. 555.

In a later study ²⁷ on the same subject, covering the Standardbred records up to and including 1913, 10 of the 11 ranking sires of speed up to that time traced directly to Hambletonian 10, and the other one traced to Hambletonian 10 through his maternal line of descent.

Another point of especial interest is that George Wilkes and Hambletonian 10, while greatly famed as the *sires of sires of speed*, yet were not famed as the direct sires of speed.

²⁷ Harper, Merritt W., Breeding of Farm Animals, p. 154.

On the other hand, Wilton and Simmons were famed as the getters of speed. It is very difficult, however, to draw any direct conclusions from a comparison of this kind, because George Wilkes and Hambletonian 10 may not have had the number or quality of mares to work on that their descendants had. Furthermore, the number of speed horses was

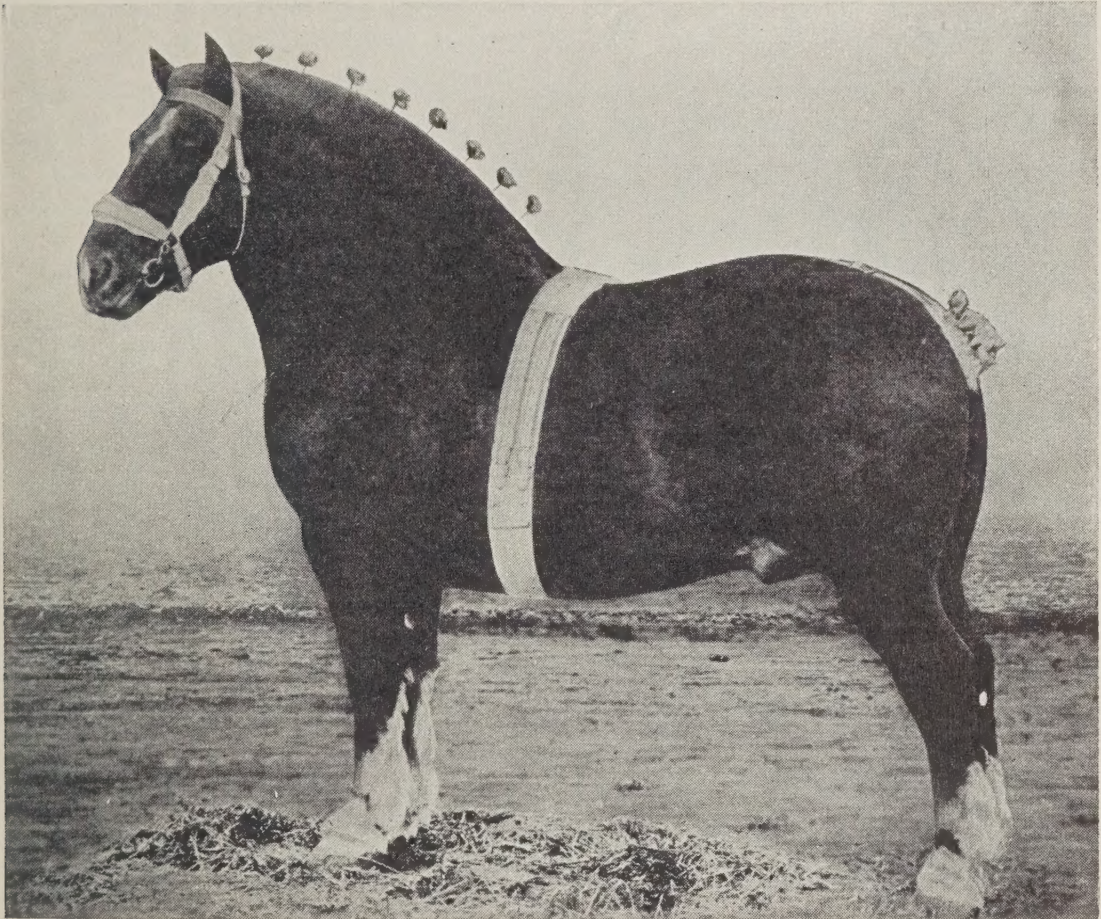


FIG. 25.—Alfred de Bree Eyck, masculinity is an indication of prepotency.
(*Courtesy Chas. Irvine.*)

being increased very rapidly about that time owing, to a considerable extent, to improved tracks, harness and care of the horses themselves; thus again their descendants had the advantage. On the other hand, the sons of Wilton and Simmons were being raced very extensively and, as racing interferes with stud work, it is very likely that their sons did not have an equal chance, with the sons of George

Wilkes and Hambletonian 10, to prove their merit in the stud.

131. Sires of Males and Sires of Females.—Breeder have long known that certain sires make good as the sires of males and others as the sires of females. Gudgell and Simpson used the Hereford bulls, North Pole and Anxiety 4th, at the same time. The latter was particularly famous

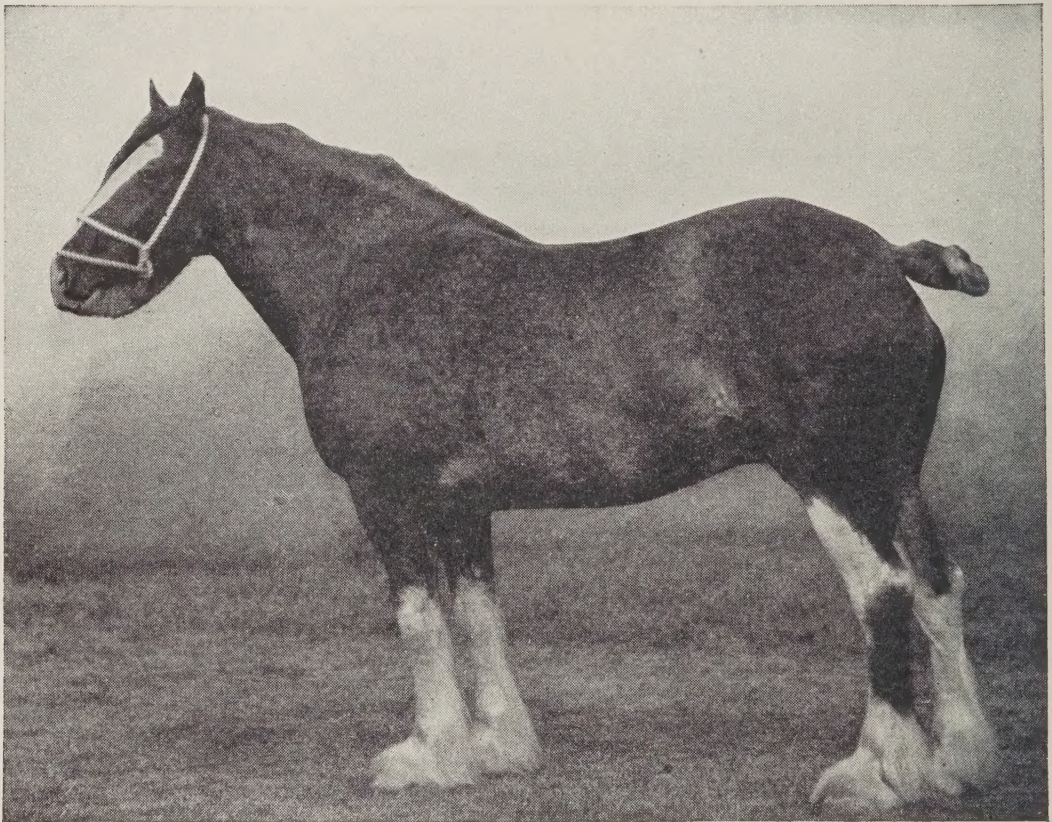


FIG. 26.—The famous show and breeding mare, Rosalind, an illustration of femininity. (*Courtesy The Field Illustrated.*)

as the sire of bulls; thus his name was perpetuated. On the other hand, North Pole was an especially good heifer getter.

132. Indications of Prepotency.—Prepotency is so desirable that a breeder will do well to consider it carefully when selecting breeding stock. The following points may be studied for indications of prepotency:

- (1) A study of the progeny.

(2) The possession of sex character—masculinity in the male and femininity in the female. (Figs. 25 and 26.)

(3) Inherent vigor.

(4) A study of the pedigree, having in mind the above-mentioned factors.

Here again enter peculiar divergencies from the rule. Old Anxiety, while a great show bull, was seriously faulted by the English judges as being too “effeminate” ever to make a good breeding bull, and Morgan was urged by many not to buy him. In this connection, Sanders remarks ²⁸ “But alas for the fallibility of human judgments!”

In general, though, the sire evincing a great deal of masculinity and vigor is the prepotent sire, and the female exhibiting a high degree of refinement and femininity is the prepotent female; but, like most rules, this one has its exceptions.

²⁸ Sanders, Alvin H., *The Story of the Hereford*, p. 423.

CHAPTER X

VARIATION

133. Variation Defined.—That “like begets like” is only partially true, for variation is inevitable. The colts by a trotting horse will trot but there may be a vast degree of difference in the way they will trot. The racial character is the unit or limit of variation—a trotting horse gets trotting colts and not draft colts. Variation may, therefore, be defined as the degree in which a character is transmitted as measured by the average of the race, rather than an entirety.

A better conception of the possibilities of variation may be gained if a character be likened to a chemical compound, several units of which, like the several elements, have been rought together to build up a certain trait. Thus, by but slight alterations of the many units, a large range of variation is made possible. Formerly, variation and heredity were considered as opposed forces; the modern conception of heredity, however, embraces both inheritance and variation. Their relationship may be understood by likening variation to a slowly but continually revolving flywheel, inheritance as the governors or controllers, and heredity as a term designated to embrace the two. The great problem of the animal breeder is to control variation; inheritance is the controller, and the more intensified the inheritance, the more complete the control. A second governing force is environment. Therefore, while the faculties of an individual are limited, in kind, to the characters of the race, they are limited, in degree, to the intensity of inheritance and environment.

134. Importance of Variation.—Variation is both the hope and despair of the livestock breeder. It is an obstacle in breeding which makes it difficult for the breeder to acquire the things he desires. To obtain success, variation must be kept within bonds and under control.

On the other hand, this existent inherent tendency to vary makes possible the improvement of domestic animals. If the characters of the offspring and the parents were identical, then improvement would be impossible. Just as an intensified hereditary force is the great controlling force of heredity, so crossbreeding is the great promoter of variation. In the development of new varieties, the breeder will induce variation, generally by crossbreeding. Usually this will involve many characters and the new generation will contain many new combinations of characters, some of which will be desirable while many will be undesirable. The individuals possessing the greatest number of desirable characteristics will be retained for breeding purposes, and the problem of the breeder is then to fix those characters or modified characters so that they will become racial characteristics and will be transmitted from parent to offspring with a reasonable degree of regularity. This he does by continued selection and by intensifying the inheritable force.

135. Classification of Variations.—To get a clear conception of any subject, a clean-cut classification is always valuable. It is so with variation. Variation, however, may be classified in various ways, dependent upon the characters involved, the continuity of the variation, and the method of its appearance, each of which will be discussed in the subsequent paragraphs.

136. Characters Involved.—Variations, as to the characters involved, may be of three kinds, viz., (1) variations in the plan of construction, (2) physiological variations, and (3) psychological variations.

(1) *Variations in the plan of construction* may be variations in size, outline or quality. Variations in size are of

the most common occurrence and may be noted on every hand, for two animals are seldom exactly of the same size. Not only will there be differences in the gross size, but these differences will extend to differences in size of parts—head, ears, eyes, etc.

Again, the plan of construction may vary as to the general outline. These differences, however, occur only occasionally, rather than commonly; they include such variations as extra teats, feet, and toes. Differences in outline may, however, call for a loss of parts as well as the addition of them; e.g., a polled calf from horned breeding, or a tailless lamb, pig, or calf (Fig. 27).

The plan of construction may vary as to quality; this is very regular in its occurrence. Individuals may be of the same size, yet there may be a vast difference in the quality of the two; e.g., in horses, the bone of one may be dense and hard, while that of the other is open and spongy. In the above case, the difference may be due to differences in the quality of the ingredients used; but again, there may be a difference in the way the same ingredients are used. The dairy steer, for instance, may carry the same amount of fat and lean meat as the beef steer, but he carries the fat as internal and external fat, rather than having it intersprinkled with the lean. Hence the difference is a qualitative one.

(2) *Physiological or functional variations* are differences in the degree of activity, as differences in the speed of horses or their ability to endure work. They deal with performance; in the dairy cow, they may be quantitative, amount of milk, or qualitative, quality of milk.

(3) *Psychological variations* are differences in mental traits. Such traits are more marked in dogs and light horses than in other classes of domestic animals, but the observant stockman is aware of the wide differences in temperament possessed even by closely related individuals of his stud, herd, and flock.

137. Continuity of the Variation.—Variations may be classified as to their continuity. In some cases, variations are continuous, while in others they are discontinuous. Continuous variation involves definite evolution, which is accomplished bit by bit—a gradual but continuous change with each generation. Stockmen are well informed regarding the evolution of our beef breeds from the upstanding, rangy, slowly maturing type to the thick, low-set quickly maturing type of to-day. This has been accomplished by continuous variation.

Discontinuous variations are usually of an abrupt nature, making a sudden departure from the old model and then breeding true to form. Discontinuous variations do not appear so frequently as the continuous ones. The occurrence of polled individuals in the horned breeds of cattle is a variation of this kind. The polled individuals appeared suddenly and then bred true to form; there was not a gradual lessening of horn until it was completely eliminated, as would have been the case had the change been accomplished by continuous variations.

138. Variations: Their Method of Appearance.—Variations may be still further classified according to their method of appearance, which may be (1) individual, (2) nick, (3) atavism, (4) reversion, (5) mutation, or (6) abnormality.

(1) *Individual variations* are the least in degree, the most regular in occurrence, and the most difficult to account for; hence the most difficult to control. On the other hand, individual variation, when supplemented by wise selection, has afforded one of the chief means of livestock improvement. It has been due to the action of the discreet breeders, in continually taking advantage of these slight but continual individual variations, that the world's yearly milk production record has been raised to 37,384 pounds by Segis Pietertje Prospect and the butterfat record to 1349 pounds by De Kol Plus Segis Dixie.

Neither full brothers nor full sisters are exactly alike. McCandlish and Winters¹ found some very marked differences in the production of purebred full sisters. The records in Table XIX were computed on the mature, five-year-old basis: considering yearlings capable of 70 per cent; two-year-olds, of 80 per cent; three-year-olds, of 85 per cent; and four-year-olds, of 95 per cent of mature production. That scale was based upon a former study made by the Iowa Station, covering over 10,000 yearly records.

TABLE XIX

INDIVIDUAL DIFFERENCES IN PRODUCTION OF PUREBRED FULL SISTERS

Group	Sister	Average Production, Pounds		Difference, Pounds	
		Milk	Fat	Milk	Fat
I	1	8309.3	394.74	599.2	75.96
	2	8908.5	470.70		
II	1	8735.2	401.55	389.7	77.85
	2	8345.5	479.30		
III	1	6213.0	294.16	3559.8	179.22
	2	9772.8	473.38		
IV	1	3345.3	175.68	4492.3	244.21
	2	7837.6	419.89		

Group II presents an interesting type of variation and not an uncommon one in dairy cattle. Sister number 1 has a greater production of milk, but number 2 has a greater production of fat, due to the greater per cent of fat in her milk. This is a case of physiological variation where the quantitative variation favored one sister but the qualitative favored the other one. Groups III and IV present marked illustrations of variation in purebred full sisters and thus exemplify how close the selection must be.

¹ McCandlish and Winters, Journal of Dairy Science, Nov., 1920.

Great as are the variations presented in Table XIX, they are no greater than the variations occurring in full sisters and full brothers of the beef, pork, mutton, or draft breeds.

(2) *Nick* is a term which may be used as either a noun or a verb. In this case, it is used as a noun, in reference to an individual far superior to either of its parents. This superiority is accounted for by the occurrence of, and the harmonious union between, affinitive hereditary units. The occurrence of this harmonious union is termed "nicking." The term is used as a verb to indicate that the mating of two animals results in the production of offspring superior to themselves. Such animals are said to nick well.

Variation, occurring as a nick, is distinguished from individual variation in that individual variation has special reference to variation in full brothers and sisters, or to only one of a few deviations from the paternal pattern; while a nick refers to a progressive variation of the offspring from their parents. If the parents nick well, not only one of the offspring will exhibit this superiority, but all, or nearly all, will do so.

Nicking is of vital concern in breeding operations. A sire cannot necessarily be condemned when he fails to get good offspring with one group of females, because it may be due to his failure to nick with that particular group of females, while with another group he might nick well. An illustration of this point is furnished in Table XX, which gives the production records of two groups of purebred Guernsey heifers and their dams, the heifers being by the same bull.²

If this bull had been used only on cows like the second group, he would have been classed as a failure, throwing daughters with an average production of 20 per cent less milk and 10 per cent less butterfat than their dams. On the other hand, had he been used only on females like the first group, he would have been considered an exceptional

² McCandlish & Winters, Journal of Dairy Science, Nov., 1920.

breeding bull, throwing daughters with an average production of 26 per cent more milk and 47 per cent more fat than their dams.

TABLE XX
“NICKING” AS ILLUSTRATED BY A GUERNSEY BULL’S PUREBRED DAUGHTERS

	Average Production			
	Group I		Group II	
	Milk, Pounds	Fat, Pounds	Milk, Pounds	Fat, Pounds
Dams.....	6305.5	264.27	7303.6	336.14
Daughters.....	8019.2	388.42	5875.3	301.62
Difference (pounds).	1613.7	124.15	−1428.3	−34.52
Difference (per cent)	26	47	−20	−10

A successful nick is a type of variation of which the breeder is always desirous when selecting a new sire. In this case he always asks, “Will he nick with my females?”

(3) *Atavism* is a French term taken from the Latin word, *avus*, meaning a grandfather. Atavism may, therefore, be defined as “grandparentism.” It is the reappearance of ancestral characters not in evidence in the parents. The occasional occurrence of red in Berkshire pigs and Aberdeen-Angus and Holstein-Friesian calves furnishes a good illustration of this type of variation.

(4) *Reversion*, like atavism, is the reappearance of ancestral characters. The difference between the two terms is in the degree of remoteness. Reversion is the reappearance of a character which was present in some remote ancestor but has not been manifest for many generations. Well-bred horses occasionally bear the markings of bars or stripes on the shoulders and legs, and, still less frequently, rudimentary gill slits occur in man. Both are illustrations of rever-

sion. Neither atavism nor reversion present new characters but rather characters not of the accepted type of the present. Unfortunately, the definitions of the two terms, atavism and reversion, are not always in accord. In many cases, the meanings given above are interchanged, and in others atavism and reversion are treated as synonymous terms.

(5) *Mutations* are variations of a marked degree, infrequent in occurrence, discontinuous, and most advantageous or destructive according to their nature. A mutation is a new character, and a mutant an individual possessing that character. The variation may be either a gain or a loss. In some cases, the character, as expressed by the mutant, is dominant to its allelomorph, but as a rule it is recessive.³

The discovery of a pair of tailless lambs by the University of Kentucky is a good illustration of mutation. In this case, it is apparently behaving as a recessive, for the ewes, when bred to tailed rams, have dropped tailed offspring.⁴ Figure 27 is an illustration of a tailless pure bred Ayrshire calf dropped in the University of Saskatchewan's herd. Its dam had previously dropped eight normal calves and its sire had sired many calves all of which were normal. The occurrence of albino calves from normal Holstein-Friesian parents (107) can also be regarded as a case of mutation, since it is caused by the absence of the color-secreting glands. The sudden appearance of polled calves in horned breeds is an old stock illustration of mutation; but it is questionable whether this is a case of mutation or of reversion, for it is known that the Egyptians, in 2000 B. C., possessed polled cattle.⁵ If these ancient cattle should in any way have contributed to the ancestry of the herds of cattle in which polled individuals have appeared, the polled character would be no more remote than the bars or

³ Babcock and Clauson, *Genetics in Relation to Agriculture*, p. 267.

⁴ Horlacher, L. J., *Information to the Writer*.

⁵ Jones, R. K., *The Field Illustrated*, Jan., 1921.

stripes which occasionally reappear in wellbred horses, and less remote than the gill slits known to occur in man.

(6) *Malformations* are variations so marked in degree as not only to interfere with the usefulness of an animal but very frequently to interfere with the continuance of its life as well. Occurrences such as two feet on one leg or a two-

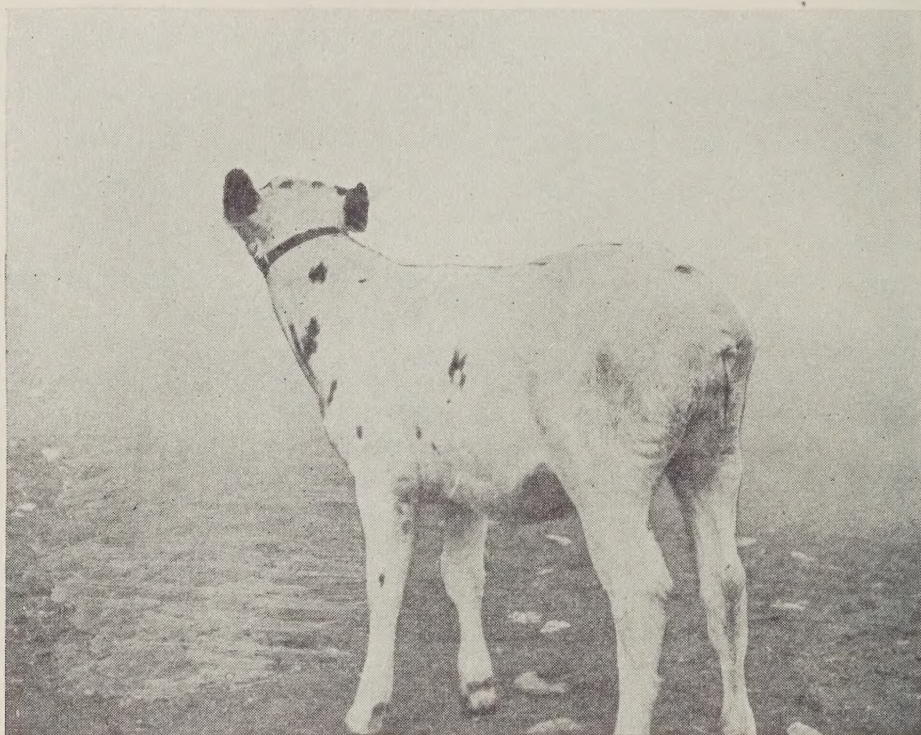


FIG. 27.—A mutant, a tailless calf.

headed individual, are illustrations of this type of variation. They, however, are of comparatively little economic importance, for they seldom, if ever, reproduce.

1. CAUSES AND INHERITANCE OF VARIATIONS

139. Causes of Variation.—Variation constitutes the basis of all improvement as well as all decline in livestock breeding. One breeder may purchase his foundation stock from the best herd in the land, but if he neglects to take account of the continual variations, his herd will decline from year to year; another breeder may purchase his

foundation stock from the same herd or even an inferior one, but by taking advantage of these continual variations he will maintain or build up an outstanding herd. Because of this, the breeder is interested in the causes of variation: they may be arranged in two main groups according to their source of origin, viz.: internal, those arising from forces within the individual; and external, those arising from without the individual. The quite generally conceded internal causes of variation are: (1) maturation, (2) fertilization, (3) Mendelism, (4) cell division, (5) fertility, and (6) longevity.

140. Variation Due to Maturation.—The very process of reduction, which the chromosomes of both the spermatozoon and the ovum undergo during maturation, furnishes a possible cause of variation. While in the main this reduction is on a qualitative basis, yet the very fact that there is a division of the chromatin material—granting that this material is as important as biologists of to-day believe it to be—furnishes a possible cause of variation.

141. Variation Due to Fertilization.—Every animal is the result of the union of two germ cells, obtained from two animals. The chromosomes of each of these germ cells apparently carry the entire hereditary contribution of the parent from which that cell is derived. During maturation the number of chromosomes is reduced to one-half; fertilization restores the normal number. Each chromosome in the ovum has its homologous chromosome in the spermatozoon, and it is certain that each chromosome is composed of genes, or factors, each of which also has its mate in the homologous chromosome. A given character of the resulting individual is, in many cases at least, the result of the influence of several pairs of genes; and each pair of genes may influence the development of several characters. Consequently, each individual and the characters of each individual are derived from the germ plasm of two individuals, and in many cases the result is due to a blend; therefore,

it would be strange if this mixing of the genes did not offer an opportunity for variation.

This does not preclude the generally accepted belief that one gene can have no influence in changing the character of its allelomorph. It merely intimates that the outcome from the coming together of several genes might be slightly different at different times. If, however, it should be proven, as many believe, that inheritance through the genes behaves with the same mathematical exactness as the mixing of a chemical compound, then fertilization could have no effect on variation.

It is noteworthy at this point that Weismann recognized this cause of variation, calling it "amphimixis." It is the only hereditary cause of variation advanced by him in his earlier writings. Later, he elaborated the theory of "germinal selection"; this theory advances the hypothesis that a struggle for existence takes place between the "biophors," with the result that some prosper and increase with rapidity while others, owing to this competition, are crowded out altogether. The variations caused by the above two factors, maturation and fertilization, are variations of the germ plasm itself. While they furnish an abundant field for the recombination of characters already present in the race, the number of racial characters discarded or the number of new ones introduced would necessarily be small. On the other hand, since by maturation the hereditary material is reduced, and by fertilization it is restored, it would be strange if the two taken together or singly did not furnish an opportunity for the occurrence of individual variations or mutations.

142. Variation Due to Mendelism.—Mendelism furnishes an abundant field for the recombination of new characters. Crossbreeding, the best means of inducing these variations, is not the only source, for every pair of mated animals—regardless of how close the similarity—present some differences in their characters; therefore, Mendelism

is at play in every mating. The variations caused by the above three factors, maturation, fertilization, and Mendelism, would naturally be expected to be capable of transmission, because they effect variations of the germ plasm itself.

143. Variation Due to Cell Division.—Each individual is the result of the repeated cell divisions of a single fertilized cell and its daughter cells. While in the main, these divisions are on both a qualitative and a quantitative basis and the ultimate size of an individual and its component parts is laid down at birth, owing to heredity, yet it would be strange if some variations did not enter into these divisions. These variations, however, could not be expected to be transmitted, because they are variations of the somatoplasm only.

144. Variation Due to Relative Fertility.—If differences in the degree of fertility are associated with different types within a breed or race, they will eventually cause a variation in the type of that race or breed; because, if the individuals of a certain type are less productive than others, they will fail to perpetuate their kind, while the others, if left to natural selection, will continue to approach the type correlated with the highest degree of fertility. Pertaining to this point, Pearson⁶ found that, on the average, daughters are taller than wives but not taller than their mothers. Since not all wives are mothers, the deduction is that, on the average, taller women within the race are more fertile than shorter ones; hence, through genetic selection, the stature of English women might be expected to increase slowly until the average height, correlated with the highest degree of fertility, is reached.

While there are no exact data available on domestic animals regarding this point, it is well known to most hog men that, on the average, the fertility of hogs decreased at the time the short roly-poly type was in favor and that it has increased with the return to a more lengthy, roomy type of sow. The relative decrease in fertility, while not the

⁶ Pearson, *Grammar of Science*, p. 441-445.

primary cause of the return to the more lengthy type, was a contributing factor.

145. Variation Due to Relative Longevity.—If a certain type within a breed or race is associated with longer-lived individuals, the breed or race type is bound to approach gradually the type associated with the longest life, just as it approaches the type associated with fertility, because the other type, because of their shorter lives, will not perpetuate their kind to the same extent as the type most closely associated with longevity.

Both fertility and longevity are factors effecting a variation of the race as a whole, rather than of individuals within the race. One would expect that the variation effected by them would be transmitted, but possibly not as an entirety.

146. Acquired Characters.—External agencies effect changes of the individual's characters, not previous to but during that individual's existence. They, therefore, give rise to acquired characters. Hence, an acquired character may be defined as a character, or the modification of an already existing character, arising through external influences, e.g., the increased speed of a race horse due to continuous training.

Unfortunately, various attempts have been made to divide the characters possessed by an individual into the two groups, acquired and congenital. Congenital characters, by the very definition of the term, include all the characters possessed by the individual at birth; while acquired characters, as already defined, include such characters or modifications of characters as may be gained during the individual's existence. In this connection, it should be distinctly borne in mind that the life of an individual commences at the time of fertilization rather than at birth; hence, any influences which may modify an individual's characters during foetal development, as an accident, would give rise to an acquired character. The terms, acquired and

congenital characters, are, therefore, overlapping and misleading. (Variations occurring through cell division are also attained during the individual's existence and are entitled to classification as acquired characters; but since the division of variations was drawn as due to external and internal forces, and any such variation is undoubtedly due to an internal force, it was discussed under that heading.)

147. Inheritance of Acquired Characters Defined.—

Those who believe in the inheritance of acquired characters maintain that individuals will be able to transmit to their offspring such modifications of characters as are attained by themselves; e.g., that the stallion or mare whose speed has been increased by development will be able to get or produce faster offspring as the result of his or her own increased speed. This is an acute question with the animal breeder, because the performance of an animal depends to a large extent upon its fitter's or trainer's ability to develop all its inherent qualities. For instance, Ringmaster and Repeater Jr., two of the greatest show bulls of their respective breeds, would never have been grand champions had they not been carefully and fully developed. The fitters of such animals like to believe that they have added something to the animals which will be transmitted to future generations.

It should be distinctly understood that the problem does not concern the origin of the acquired character, which is, beyond dispute, a matter of the somatoplasm only, but the transmission of the acquired character, which implies an influence of the somatoplasm upon the germ plasm. In other words, it is recognized that improved environment may modify the somatoplasm; but will it likewise modify the germ plasm? In most cases, the acquired character is a character already existing, but modified, and the question is: "Will it be transmitted as modified rather than in its original form?" Stated in specific livestock terms the question is:

(1) Will the daughters of De Kol Plus Segis Dixie be higher producers as the result of her having been developed to produce 1349 pounds of butterfat in one year?

(2) Will the offspring of Man-o'-War inherit greater speed as the result of his having attained a 1:35:45 record?

(3) Will Bar Marshall's calves be more beefy as the result of their sire's having been developed so as to attain International grand championship honors?

(4) In brief, will future generations take their start from the plane of improvement to which their ancestors have been developed?

The problem of the inheritance of acquired characters is one of the old biological controversies. The fact of evolution is no longer an open question, but the method of evolution is not entirely settled.

148. Beliefs in the Inheritance of Acquired Characters.—It is in the works of Aristotle, the ancient philosopher, that we find the first indication of belief in the inheritance of acquired characters; in fact, most, if not all, of the ancient philosophers firmly believed in their inheritance. Lamarck, at a much later period, was the first to set forth clearly a hypothesis for their inheritance. He formulated two laws: first, that changed environment wrought changes in an individual's various characters; second, that that individual was able to transmit these characters, as modified, to its own offspring. Lamarck has had many followers (called Neo-Lamarckians) up to and including the present. They have, however, modified the original hypothesis, believing, for the most part, only in the inheritance of achieved characters and not in that of thrust characters. The belief in the inheritance of thrust characters (mutilations) is too easily disproved by such instances as the circumcision of the Jew, the deforming of the feet of Chinese women, and the continued practice of dehorning cattle, clipping the ears of dogs, and docking horses and sheep. These practices, although continued for many generations,

have not wrought any visible changes in the transmission of the original characters.

It will be remembered at this point that Darwin's theory of pangenesis was founded on belief in the inheritance of acquired characters.

There is a rather widespread belief among breeders that acquired characters are transmitted. It is frequently very difficult to explain, to the light horseman's entire satisfaction, that a "high schooled" horse will not be able to transmit his fancy steps to his offspring in a greater degree as the result of his own development. Likewise, many breeders of beef cattle believe that by continually keeping their herd in good condition they will develop a more beefy herd of cattle.

149. Opposed Views.—It was Weismann who led the opposition to the theory of the inheritance of acquired characters. His theory of the continuity of the germ plasm (90) was directly opposed to this belief, this theory being that the body merely acts as a host to the germ plasm, and that a little bit of the original germ plasm is carried forward with each generation. In other words, given a start in germ plasm, this germ plasm is the foundation of the next generation, each individual of which consists of body plasm which serves as the host for a small amount of the original germ plasm. The body plasm ends with each generation, but the germ plasm of each generation is the source of both the body and the germ plasm of the succeeding generation.

Weismann's reasons for not believing in the inheritance of acquired characters are still considered sound by leading biologists; they are as follows:

(1) There is no known mechanism whereby the body plasm may influence the germ plasm.

(2) The evidence presented in support of belief in the inheritance of acquired characters does not, in a single instance, satisfy the rigid requirements of an experimental proof.

(3) The theories of the continuity of the germ plasm and germinal variation can account for all known facts of heredity without assuming the inheritance of acquired characters.

150. Conditions Necessary to Prove the Inheritance of Acquired Characters.—Proof that acquired characters are transmitted must naturally be the result of a most exact experiment. Weismann maintained that such evidence, to satisfy the rigid requirements of an experimental proof, must fulfill the following conditions:

(1) A specific somatic character or modification must be impressed upon the organism by a known external factor.

(2) The character or modification must be new; there must be no question of the reappearance of ancestral traits or characters.

(3) The induced change must reappear in succeeding generations in the absence of the original factor which determined its production. The change in question may, however, be present in a lesser degree in the immediate descendants and in succeeding generations, in the absence of the original stimulus.

151. External Causes of Variation.—The most frequent external causes of changes in the body plasm are (1) mutilations, (2) climatic changes, and (3) feed. The improbability of the inheritance of mutilations has already been discussed (148). The changes caused by the other agencies and the possibilities of their transmission to succeeding generations will be discussed in the subsequent paragraphs.

152. Variations Due to Climate.—Close observers of animals have been immensely impressed with the wide differences of characters exhibited by representatives of the same breeds under different climatic conditions. Darwin observed that in India the bulldog rapidly lost his ferocity and that the hound declined with even greater rapidity.

Most breeds do best in their native climate, but not all: the Hereford is apparently at his best in America; Merino

sheep originated in the tablelands of Spain, but they have apparently found a more favorable climate in France, America, and New Zealand. Selection and feed are also contributing factors, and it is generally difficult to say just how much each of these factors contributes to the modifications in question.

153. Variations Due to Feed.—Feed supply is one of the greatest direct causes of variations of form. A good illustration of the variations due to differences of feed supply is to be found in the Galloway and Aberdeen-Angus breeds of cattle: both were developed on the same island and very probably both rest on a common foundation. The Galloway, developed where feed is rather scarce, is neither so smooth and round nor does it mature so early as the Aberdeen-Angus. Here again, selection has without question played a prominent rôle. A better illustration is to be found in the Shetland pony, a diminutive breed developed in the barren islands of Shetland; when these ponies are moved to America, where they are fed more liberally, they tend to increase in size.

That the factors of feed supply and climate are capable of effecting variations is beyond dispute. The question under discussion is: Can the animals so affected transmit these variations to their offspring? To prove that such was the case the bulldog, when returned from India to Britain, would have to show no *marked tendency*, in succeeding generations, to revert to the more pugnacious temperament of his British ancestors and cousins; likewise, the Shetland pony, when returned from America to the Shetland Isles, should show no *marked tendency*, in succeeding generations, to revert to the ancestral type.

The belief that increased feed effects variations in the body of an animal and that these variations can be transmitted to that animal's offspring is quite prevalent among farmers. The farmer finds, when keeping his beef herd in high flesh year in and year out, that he gradually develops

a more beefy herd; hence it is but natural that he should believe in the inheritance of the increased beefiness. The point he fails to take into account is that by keeping his herd in good condition he paves the way for selection; i.e., the best "doers" in his herd are discernible and these are retained. Hence, liberal feeding has aided selection; and selection, by taking advantage of the continual variations, has accomplished the improvement.

154. Variations Due to Use and Disuse.—It is an undisputed fact that use develops an organ while disuse dwarfs it. There is no doubt that, over many generations, the continued use of certain parts may effect considerable modifications of those parts from the original, or that continued associations over a like period may effect a wide variation of temperament from the original. A good illustration of variation due to this factor is to be found in the English sheep-dog. His remote ancestors were killers of sheep; but the sheep-dog of to-day is a lover and protector of sheep. The question then is: Has association itself, over a long period of years, effected this change? A more probable explanation would be that the change has come about in a different way: The dog was very probably the first animal domesticated by man; shortly after this, man took to herding sheep and later cattle. In these early times, man looked upon the dog as something apart from or above other animals, and only resorted to using him as food in cases of the most dire necessity. (In Darwin's studies of primitive tribes, he found those who, when short of food, would prefer to use old women of the tribe rather than part with their dogs.) It would be strange if at these times they did not kill the dogs giving them the most trouble as sheep killers; and this practice, continued over many generations, was bound to cause an immense change in the temperament of the dog. Later, as the dog became more useful, man retained the most useful and kindly tempered ones, which would cause an even more rapid change. Thus the change from a

sheep killer to a sheep lover was probably effected only indirectly by association, but directly by selection.

The owner of fast horses frequently finds it difficult to believe that his stallion will not sire faster offspring after lowering his own record. And in support of his belief, the records in most cases will indicate that his stallion has sired faster offspring following the reduction of the stallion's record. A point not often considered is that the stallion, through his reduced record, has attracted a more speedy class of mares; hence, he has a better chance to sire faster colts.

155. Variations Due to Disease.—Certain diseases, without question, effect modifications of the body organs; the question then is: Is either the modification or the disease capable of transmission? The frequency of tuberculosis in both children and calves from tubercular mothers has repeatedly been pointed to as an illustration of the inheritance of disease. It has, however, been demonstrated that if calves are removed from their tubercular mothers at birth, they are no more likely to develop the disease than any other calf. The stockman thereupon asks: Why is it, then, that the stallion with some unsoundness, e.g., spavin, gets so many offspring with the same affliction? The answer is: He himself has a faulty hock conformation which is responsible for his having developed the unsoundness; his hock conformation is transmitted to his offspring; consequently, a large percentage of them likewise develop the unsound hock.

156. Variations Due to Poisons.—Numerous data have been gathered showing that the children of habitual drunkards are far more disposed toward insanity than the children of parents not so affected. The inference drawn is that drunkenness causes insanity in succeeding generations. This inference is very questionable, since the data deal with a selected population and it is above reproach to ask the question: Was there not a previous impairment in the mentality of the man who is habitually intoxicated?

Various experiments with laboratory animals have been conducted to determine the effects of alcohol on the progeny, but the results are decidedly conflicting. In some cases, the offspring suffered markedly; in others, there was no apparent change; while in still others, the offspring, over a series of generations, were markedly more intelligent, more robust, and larger. The cases of deterioration should not be explained as evidence in favor of the inheritance of acquired characters, but by the fact that if alcohol acts as a poison to the body cells there is no reason why it might not affect the germ cells in a like manner. The improvement, in the third group, is explained as a case of selection or survival of the fittest of the germ cells.

It has also been noted that children of lead workers are more frequently defective than other children. Lead is a deadly poison affecting the body plasm, but, as in the case of alcohol, if it can cause a deterioration of the body cells there seems little reason why it might not effect a similar change on the germ plasm. This, therefore, would not be a case of the inheritance of acquired characters.

157. Further Proof.—Up to this point, the argument presented against the inheritance of acquired characters has been of an explanatory nature, explaining how the apparent inheritance may have taken place. Fortunately, however, experimental work bearing on this point is available. Some thirty years ago, Heape removed the fertilized egg from the oviduct of a *long-haired white* rabbit, she having been served by the same type of male, previous to its attachment to the uterine wall, and transplanted the egg to the oviduct of a *short-haired gray* Belgian hare. The offspring so produced were in every case unaffected by the individual characters possessed by their foster mother but were *long-haired and white* like their real mother. Castle and Phillips⁷ conducted an even more convincing experiment. The ovaries of an albino guinea-pig just reaching sexual maturity were

⁷ Castle and Phillips, Carnegie Institution of Washington, No. 144.

removed and replaced by the ovaries of a black guinea-pig not as yet sexually mature. Previous experiments had shown that if a black guinea-pig were mated with a white one, the offspring would be black, since black is a dominant color; and that if normal whites were mated, only whites might be expected. The above-mentioned white guinea-pig, bearing ovaries from a black guinea-pig, was later thrice mated to a white male guinea-pig, and on each occasion produced black offspring. As the last litter of young was produced about a year after the operation had been performed, ample time had taken place for the body cells to affect the germ cells, if they possessed any ability to do so.

2. COMMON BELIEFS REGARDING CAUSES OF VARIATION

158. Classification of.—That the human mind wishes to believe in myths is nowhere better exemplified than by the persistency with which certain fantasies, regarding supposed causes of variation, have endured in spite of scientific facts. These beliefs have frequently been classified under acquired characters and their inheritance. An acquired character is admittedly the modification of some character by a specific environmental factor. These beliefs pertain to the supposed modifications of an individual's characters, previous to birth, by certain factors; but as it is not admitted by biologists that these factors possess power to effect such modifications, the latter cannot logically be classified under acquired characters.

These fantasies embrace the beliefs known as *telegony*, *saturation*, *infection*, and *maternal impressions*.

159. Telegony.—*Telegony* is the supposed influence of a sire on the females with which he has been mated, this influence being believed to extend to later offspring out of these females but by another sire; i.e., it is the supposed influence of a previous impregnation.

The belief is an old one, having been accepted by Darwin

and Spencer. The classical illustration of telegony is Lord Morton's mare, mentioned by Darwin. The mare, a seven-eighths Arabian of chestnut color was, in 1815, bred to a quagga, the result being a true hybrid bearing the sire's color and other characters. Later, the mare produced two foals by a black Arabian stallion. Both foals were described as bearing resemblance to the quagga; both possessed dark stripes across the forehead and the legs, and a dark line along the back. This illustration came to be an accepted proof of telegony.

In order to put this belief to the test of an experimental proof, Ewart, in 1895, commenced a breeding experiment whereby 13 mares of varied colors and breeds produced 16 hybrid foals by a zebra sire. Later, the same mares, bred to Arab, Thoroughbred, and Highland stallions, produced 22 foals. One of these foals, out of a black Highland pony and by a gray Arab stallion, bore stripes somewhat after the fashion of the zebra; and this at first caused Ewart to believe that the dam's previous mating to the zebra had influenced her later offspring. But later, purebred foals more vividly striped were got by the same Arab stallion when used on other Highland mares which had never seen a zebra; thus it became evident that the above experiment contained no evidence in favor of telegony. All the other foals by Arab or other stallions and out of the mares having previously produced hybrids, bore no resemblance whatever to hybrids. Hence, the one foal in this experiment bearing some resemblance to a zebra and the one mentioned by Darwin may both be regarded as cases of coincidence, because it is not unusual for foals to be produced exhibiting more or less of the barred markings.

If telegony were possible, mule-breeding districts, where mares are frequently bred to a jack one year and to a stallion the next year, should afford exceptional opportunities for its appearance. Mumford,⁸ in a very thorough investi-

⁸ Mumford, F. B., *The Breeding of Animals*, p. 170-176.

gation of possible cases of telegony in Missouri, the heart of mule breeding in the United States, found only disproof of telegony: of the 168 horse foals from mares which had previously produced mule foals, not one gave any visible evidence for belief in telegony.

In addition to the evidence mentioned above in opposition to telegony, the belief is not justified in the light of present-day knowledge regarding the physiology of reproduction, for there is no known means by which the effects of a previous impregnation might be carried over by a female.

160. Saturation.—Saturation is the supposed cumulative effect of telegony, the supposition being that in the production of full brothers and sisters, the successive generations assume more and more resemblance to the sire. Belief in this doctrine has never been so widespread as that of telegony. It, like telegony, can be discarded in the light of present-day known facts regarding reproduction. In addition, some statistical evidence was gathered by Pearson covering the possibility of successive children's more nearly approaching their father's height and arm length: the study gave no indication whatever of the cumulative effect of a sire.

161. Infection.—There are two beliefs regarding infection. One is that a sire may become infected through serving a female, so that subsequent females served will produce offspring bearing resemblance to the first female; i.e., if a purebred Shorthorn bull first served a Hereford cow and later a Shorthorn cow, the latter's calf might bear some resemblance to the Hereford cow.

The second belief regarding infection is that a female may become infected by the male with which she is mated, so that she herself will take on a likeness to him; i.e., if a mediocre milk cow is, year after year, mated to a sire of high-production breeding, the cow herself may be expected to improve in her producing ability.

Both beliefs are mere fantasies. They are not founded on facts, and any apparent cases can be explained as cases of coincidence.

162. Maternal Impressions.—The belief in maternal impressions has been one of the most persistent of these beliefs. It is that the developing foetus may become impressed by any unusual sights or experiences encountered by its dam, and will bear resemblance to these impressions. The story is that McCombie of Tillyfour had erected a high black board fence around his breeding paddock, believing that by so doing he was more likely to get black calves. It may be that he had the fence painted black for that reason, and it may be that he had it painted black because he liked black; but in either case, it is no proof that the calves so produced were more completely black or a deeper black as the result of this fence. Peculiarly marked offspring, both in humans and domestic animals, are said to owe their strange markings to certain objects or colors seen by the mother while pregnant. Since pregnant females see a wide variety of objects, it is not difficult to recollect some object seen by them during pregnancy bearing resemblance to any unusual marking or deformity of the offspring. Furthermore, there is no known mechanism whereby such impressions might be made upon the foetus, and in the light of experimental evidence (157) such beliefs are easily disproved.

163. Accidental Matings.—While many of the supposed cases of telegency, infection, and maternal impressions are no doubt mere instances of coincidence, it is not necessary to explain all cases by that means, for accidental matings do occur. A case of this kind, which the writer has in mind, was that of a white turkey hen which was taken by her owner to a farm, a mile distant, to be mated with a bronze gobbler. She produced and reared a batch of yellow to brownish turkeys, as is quite common when farm turkeys of this kind are crossed. After this she began laying again,

and produced a fall batch of turkeys of the same kind, although she was not again taken to the gobbler and her owner was confident she never left his farm. One of three things must have happened: some of the sperm cells penetrated undeveloped ova and caused a fertilization that bore fruit later on (an occurrence which was at one time deemed possible); some of the sperm cells lived over and caused the later fertilization; or, by clandestine means, the hen met the gobbler. The first possibility is extremely unlikely according to present-day knowledge regarding reproduction, and the second is also unlikely as most poultry experts consider eggs infertile when a broody spell intercepts laying and a second copulation does not take place; therefore, it is more likely that a second copulation took place. The point is this: if she had purposely been mated with a white gobbler and had still produced this second batch of turkeys, colored as they were, it would have been considered evidence in favor of telegony.

Still another case of the same kind: a Hereford heifer owned by the University of Saskatchewan, and not knowingly bred, dropped a calf with black and white markings. If she had previously produced a calf by a Holstein-Friesian bull, this occurrence might have been considered as grounds for belief in telegony; on the other hand, if she had intentionally been bred to a Hereford bull that had been used on Holstein-Friesian cows, it might be cited as a case of infection of the male; while if intentionally bred to a Hereford bull but kept in the same barn with the Holstein-Friesian bull, the same case might be cited as an illustration of maternal impressions.

PART IV

THE PRACTICE

CHAPTER XI

THE DEVELOPMENT OF BREEDING

164. Breeding an Art.—A breeder may be defined as one who, by the close study of his animals, regarding both their own and their ancestors' individuality, endeavors to so mate them that the offspring will be superior to the parents. Mating without this close study is mere propagation.

The study of animal breeding, since it involves heredity and the physiology of reproduction, is a science; but the practice of animal breeding is an art, because the results are approximate rather than exact. In animal breeding $2+2$ does not always equal 4; at times it may equal 5, which is the result the breeder works and hopes for; but far too frequently it equals only 3. The production of offspring superior to their parents is an art of the very highest type and calls for a man who is an artist to the *n*th degree.

Like the sculptor or painter, the breeder too must have a model; but unlike them, he cannot work in the presence of his model. The problem of the sculptor and painter is to mold or put on canvas an exact reproduction of his model. The breeder's problem is to produce a living specimen, the model of which he has in all probability never even seen, for there are few, if any, perfect animals. Therefore, his model must necessarily be but a vision of the perfect animal he wishes to produce.

Like the painter and the sculptor, he too must study and understand, as fully as possible, the tools and the ingredients with which he works; hence the study of reproduction, heredity, and pedigrees; but unlike them he is able

to gain but a partial knowledge of his tools and ingredients. Furthermore, he works with tools and ingredients which are, of necessity, imperfect ones.

165. The Domestication of Animals.¹—The domestication of animals naturally began at a more remote period than the recorded history of man; for man's own evolution from savagery to domesticity is very directly associated with his domestication of, and association with, animals. Practically all the work of domestication has been done by the Asiatic peoples, and principally by the Aryan race. While in some instances the American Indian is known to have tamed the llama and alpaca, and later wild horses (descendants of horses which escaped from the Spaniards), yet he failed to tame the turkey, duck, goose, and deer, all of which might have been domesticated had he been so inclined. The peoples of Africa show the same lack of disposition to tame wild animals.

The dog was, with but little question, the first animal tamed by man, and it is indeed gratifying to reflect that he was not tamed for material gain but for the sake of companionship. It is quite likely that for a long time the dog was used only for companionship and as a reserve food supply, for the dogs of savages are much like their masters—creatures of but little intelligence. Gradually, however, as man's own intelligence increased, he made use of the dog, and consequently, by continued selection through the ages, a useful type of dog was evolved, and by still further selection the different breeds were developed.

It is very likely that the horse was the next animal to be domesticated, and this very possibly took place first in northern Asia, long before the appearance of authentic records. Apparently, the horse was first used for saddle and pack purposes. At no time and by no people has the horse been extensively used for human food. This is undoubtedly due not to a distaste for the meat, but to a

¹ Shaler, N. S., Domesticated Animals.

sympathetic feeling of man toward his helpmate, and the development of this feeling in man evidently contributed as much toward his own evolution and betterment as his use of the horse. The horse was at first most prized for war purposes, and he gave his possessors a great advantage over their unmounted adversaries. Shortly afterward, he was used by wanderers for conveyance, but not until comparatively recent times has he been used for agricultural and industrial purposes. Even in this day of mechanical contrivances, man would miss the horse as much, if not more, than any other animal, if for some reason his existence was wiped out.

Cattle, sheep, pigs, and birds were first hunted for purposes of food and clothing. Finally, man conceived the idea that by herding and caring for them during the times of feed scarcity, he would be more assured of a food supply. As the ox and the buffalo (Asiatic) became tamer, man perceived that he might use them as beasts of burden, and they were so used long before the horse.

Two other animals extensively used by man in other parts of the world are the camel and elephant. Their use dates far back beyond the beginnings of accurate history, probably beginning about the time the horse was first used.

166. Effect on Man.—In man's egoism, he is likely to forget that it is he—not the animals—who has derived the greatest amount of benefit from this association; and this benefit is by no means only economic, for it is very closely linked with man's own evolution from savagery. Just as soon as he undertook to bring animals under his supervision, various problems presented themselves, such as the protection of flocks and herds from predatory animals and men, the provision for a constant feed supply, the treatment of injuries and sickness, the best uses to be made of animal products, and the other very numerous problems connected with the handling of livestock. All this taught man to think, and gradually, as the years passed, he gave

more and more thought to this problem, all the while developing his own mental facilities, as well as providing a more comfortable life for himself and his family. The peoples most advanced in the uses of livestock were not only better situated economically to undergo warfare, but their mentality was developed so markedly that they were able to push the other peoples aside, as they wished more room, and hence the survival of the fittest came into play.

A benefit which was derived by man from his association with animals, and which meant much to him, was the development of his sympathies. Not only does man radiate more happiness as he becomes more sympathetic, but one need only scrutinize any large crowd to observe that the sympathetic man derives more real pleasure and satisfaction from life. To gain proof that association with animals tends to develop this side of man's nature, one need only visit any successful herdsman, shepherd, or groom in the care of his charges. The very success of his enterprise depends to a very large extent upon the kindly care given his subjects. Thus, in all these ways, animals have had a tremendous influence on man's evolution from savagery, and fortunate indeed is the boy or girl who is allowed the privilege of growing up with the association of good livestock.

167. Animal Rights.—The far too prevalent idea that all animals were created solely to satisfy man's many varied needs and pleasures is but another of his many egotistic beliefs regarding his own importance. Unquestionably, animals are to be used for such economic and pleasure-giving purposes as they may serve without suffering cruelty to themselves. The humane societies in all our large cities have made great strides toward the betterment of the conditions under which animals live. Too frequently, however, one still sees attempts to back a wagon where the horses, if left to their own judgment, would do a better job than with the misguidance and jerkings of a brutal teamster; too

frequently one sees a willing dog flogged merely because he does not understand what he has never been taught; too frequently the cow receives her sole education by means of the milk stool, with the not surprising result that her response is in keeping with her teaching. These are but a few of the many unnecessary cruelties to which animals are repeatedly subjected. Not only is such treatment inhuman, but it is inefficiency in the most exaggerated form, for animals respond more readily to kind treatment. The sooner all those engaged in the handling of live animals come to recognize that animals have a right to civil treatment, the sooner will they come to reap the full reward—both financial and moral—that comes to those who are intrusted with the care of, and association with, live animals.

168. Possibility of Further Domestication.—Wild life is fast being eliminated from this continent, and before any class of animals becomes extinct we should ask whether it would not be possible and desirable to make some place for that class of animals within our domestic circle. It has been proven that the bear, the moose, the deer, and the fox (Figs. 28 and 29) are capable of domestication, and there is a possibility that the bison could be domesticated. It is very possible that for certain sections of this continent, where conditions are very adverse on account of cold or the scarcity of vegetation, the bison might be more adaptable than European cattle; and if the same care and selection were given to matings, there is no reason why a like improvement might not be made in his form. Likewise, the deer and moose will graze in many places where cattle would die, and the bear will make his living in the rough mountainous sections. All these animals have economic uses that should be carefully considered before they are all but completely destroyed.

169. Early Breeding.—The improvement of livestock by controlling the parentage undoubtedly goes beyond the time of Prince Mehenwetre of Egypt, who reigned about

2100 B.C.² In 1919, a chamber, previously overlooked, in the tomb of this prince, was discovered and opened for the first time since it was closed by the Egyptians over 4000 years ago. This chamber contained models of Egyptian life, more nearly perfect than any that had, up to that



FIG. 28.—Foxes are becoming domesticated. (*Courtesy The Black Fox Magazine.*)

time, been discovered. It was the Egyptians' custom to bury with the deceased his tools and weapons; and in the case of the wealthy they included many additional articles, such as figures of servants at their daily work and miniature models of the many and varied possessions of the deceased. In this particular chamber, models of cattle,

² Jones, R. K., *The Field Illustrated*, Jan., 1921.

barns, a brewery, a bakery, an abattoir, and many other illustrations of their daily life were found.

The largest of these models showed the prince counting his cattle as they passed by. The census, which was found, disclosed that he owned 835 long-horned cattle, 220 polled cattle, 750 donkeys, 974 sheep, and 2234 goats. Apparently the Egyptians were fairly well versed in the arts of animal breeding, as one of the models illustrated the difference in



FIG. 29.—Deer respond readily to domestication.

type between the wild animals and the improved ones (Fig. 30). As mentioned above, polled cattle existed at this early period (Fig. 31), and it is also quite certain that there were different beef breeds, each of which had its partisans.

The art of feeding is seemingly also an old art, for one of the models illustrated cattle in the process of being fattened. Furthermore, the art of curing meat is apparently not a new one, for the model illustrating an abattoir showed

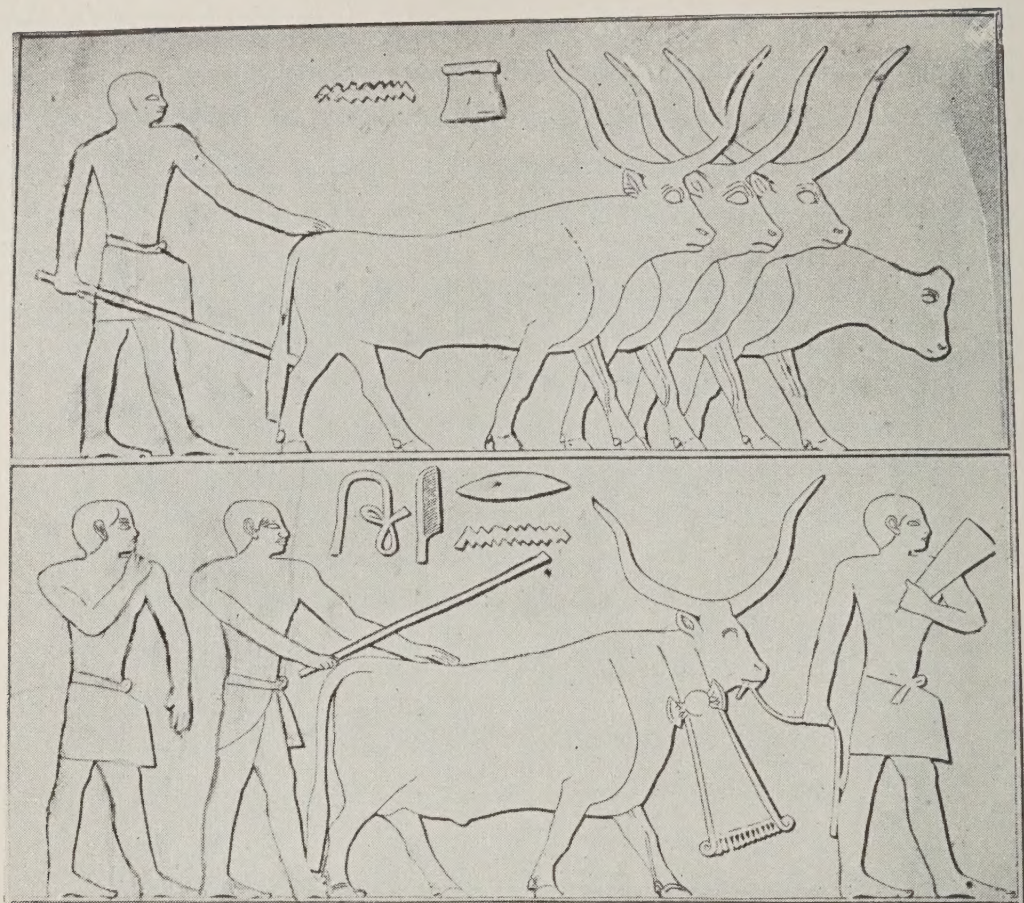


FIG. 30.—An Egyptian model illustrating the difference in type between improved and unimproved animals. (Courtesy *The Field Illustrated*.)

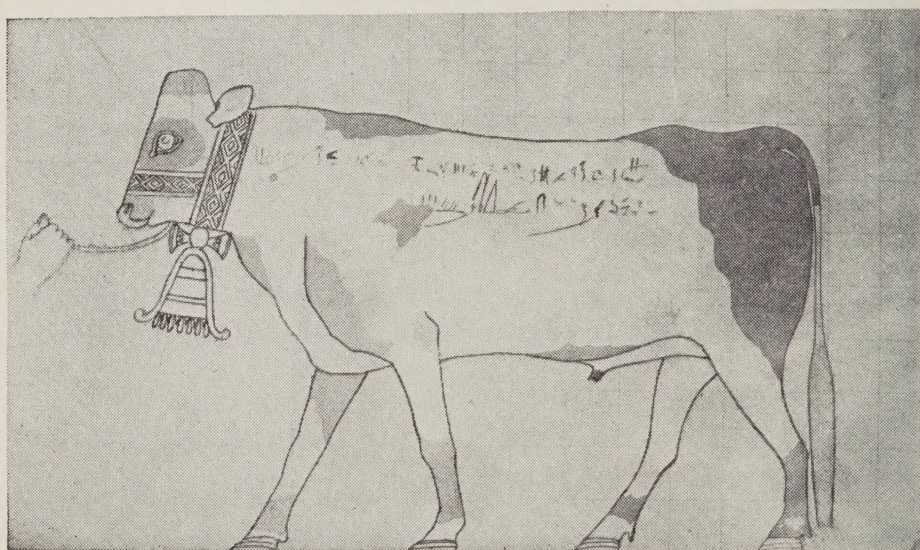


FIG. 31.—An Egyptian model of a polled bull. (Courtesy *The Field Illustrated*.)

meat evidently being hung up to dry. The tomb of King Tutankhamen, opened in January, 1923, contained great quantities of canned meat in a perfect state of preservation after having been sealed for approximately 3000 years.

Another of the early peoples who took great pride in their breeding operations were the Arabians. Just when they first gave serious consideration to the breeding of horses is unknown, but it is known that about 1635 B.C. Sheik Salaman owned five famous mares from which have descended the purest and the best Arabian horses. The early Arabs fully appreciated the great advantage they enjoyed in the superiority of their horses, and thus cleverly and wisely created an atmosphere of mystery about their breeding operations, so as to guard against the dissemination of their methods and thus retain for themselves the mastery of the art that it had taken so long to attain. It is also known that the Arabs, even in these early times, practiced artificial insemination.

At a somewhat later date, we find the Romans taking great pride in their horses. Still later, the French and the British Governments promoted the improvement of their horses in order that their armies might be better horsed.

170. Robert Bakewell.—The development of modern breeding, however, dates from 1760, when Robert Bakewell assumed the management of the estate on which both his father and grandfather had resided, at Dishley Grange, in Leicestershire, England.³ He may be thought of as the pioneer breeder who paved the way for the development of most of our modern breeds of livestock.

Robert Bakewell's contributions to the progress of livestock breeding may be summed up as follows:

(1) He saw that the stock then raised did not meet the requirements.

(2) He sought a more productive animal.

(3) He had an ideal.

³ Journal of the Royal Agricultural Society, Report for 1894.

(4) He saw that a relationship existed between beauty of form and utility.

(5) He realized that symmetry was an essential point, especially so regarding the percentage of offal to the dressed carcass and of bone to muscle.

(6) He saw that the quality of the meat depended upon the texture of the flesh.

(7) He aimed for easy feeding and rapid fattening.

(8) He maintained that a relationship existed between breeding inheritance and the above-mentioned characters; and furthermore, that to attain the best results, breeding was dependent upon feeding.

Bakewell achieved his greatest success in the breeding of Leicester sheep; yet he made considerable progress in the improvement of Longhorn cattle and Leicestershire Cart Horses.

Bakewell was not only the foremost breeder of his day, but he was also a keen business man and leased many bulls and rams at high figures. This practice helped to stimulate other people's interest in the improvement of livestock, and undoubtedly the greatest good accomplished by his work came from thus awakening the people to the needs for improvement.

It was maintained that Bakewell worked in secret and would not divulge his methods. It is very easy to understand how this impression got abroad, for even to-day many believe that by some outside influences the developing foetus may be greatly changed in character. Furthermore, it is very likely that Bakewell really had no message or instructions to give, outside of his most apt instructions, which were, "breed the best to the best," and "like begets like."

171. Other Pavers of the Way.—While Robert Bakewell is looked upon as the father of modern breeding methods, yet many others, at about the same time, were working out their own problems in much the same way. Among

these pavers of the way were the Tompkins and Galliers families, who early in the eighteenth century, began improving the Herefords; Hugh Watson, McCombie, and Fullerton, who at a later period laid the foundation for the Aberdeen-Angus; and John Paterson who, about 1715, began in a constructive way to improve the draft horses of Scotland. To include all the numerous men who have given the best of their lives toward the improvement of livestock would be to enter on another subject, The History of the Breeds; but no such list would be complete without including the names of the old Quaker, Amos Cruickshank, Sir George Macpherson Grant, and our own Gudgell and Simpson, all of whom practically revolutionized the type of their respective breeds.

172. Formation of the Breeds.—Before a breed could be founded and called a breed, it was necessary for it to go through a long process of being shaped to definite form and type. This shaping of the breeds was, for the most part, undertaken with no idea—on the part of the breeders—of forming a breed, but rather of developing a type of animal better suited to their particular needs. A good illustration of this is to be found in the case of one of our own American products, the American Saddle Horse, as fine a product as ever graced the hands of any group of breeders. The formation of the breed goes far back to Colonial days when the planters of Virginia and Kentucky began developing a type of saddle horse that better suited their needs, a horse that was easy riding but could yet cover long distances. The exact establishment of the breed, however, did not take place until 1891, when the American Saddle Horse Breeders' Association was organized.

173. Breeding Methods and Terminology.—During the past two centuries of livestock improvement, various quite clearly differentiated methods of livestock breeding have come into practice. These are closebreeding, crossbreeding,

and grading, each of which will be discussed in the subsequent chapters.

Before entering the above discussion, it is, however, well to have in mind a clean-cut understanding of the following terms:

(1) A purebred animal is one that is registered or eligible to registry in the record books of its breed. More generally speaking, however, it is an individual whose parents are purebreds and of the same breed.

(2) A scrub is an individual of nondescript parentage.

(3) A grade is an individual one of whose parents is a purebred—generally the sire—and the other a scrub or a grade.

CHAPTER XII

CLOSEBREEDING

174. Closebreeding Defined.—Closebreeding is the mating of animals which are more or less related. In closebreeding the number of ancestors is reduced, but the number of ancestral places necessarily remains the same. The principle involved is the purification of the ancestry, which is accomplished by the elimination of all ancestors of undesirable character through the repeated use, in as many ancestral places as is possible, of individuals of known prepotency and breeding merit. It goes back to the rule that the average of the ancestors will equal the average of the progeny (119). In short, closebreeding is the doubling up of the ancestral force.

The pedigree of Fairholm Footprint is a typical illustration of closebreeding (Fig. 32).

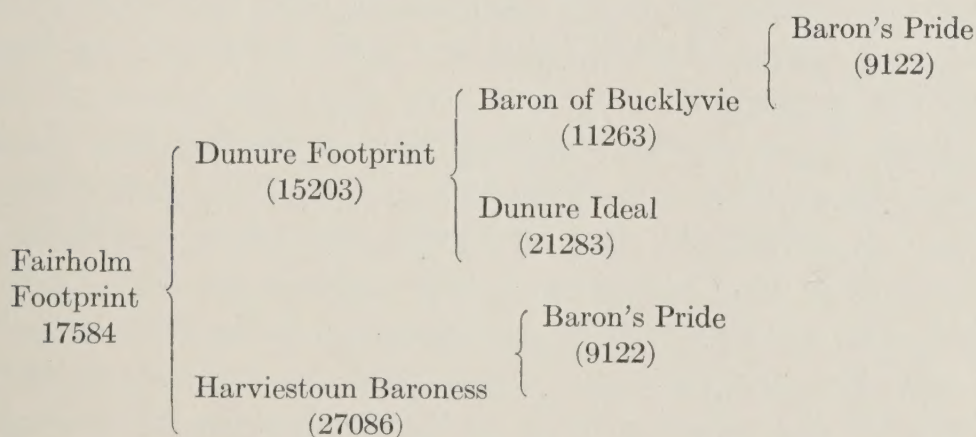


FIG. 32.—The pedigree of Fairholm Footprint 17584, an illustration of closebreeding.

175. Reasons for Closebreeding.—The closebred animal is the prepotent one, by reason of the fact that no new

characters are introduced, but the good qualities which the breeder already has in some animal and is striving to make dominant are intensified in the offspring. By this concentration or intensification of the offspring's hereditary characters the closebred animal necessarily becomes prepotent, which is the most important characteristic in a highly improved breeding animal. Closebreeding is the quickest and the surest method of fixing and perpetuating a desirable character or group of characters.

There is another reason for closebreeding: it frequently has happened, in the development of certain breeds, that some breeder was so far advanced over other breeders that for him to go outside for breeding animals would have been a step backward, just as if a man of to-day who possessed a well-graded herd should revert to the use of scrub sires. When a breeder cannot go outside and procure animals as good or better than his own, then there is only one thing left for him to do—closebreed.

176. Disadvantages of Closebreeding.—Closebreeding frequently inclines to definite results of a general character quite independent of the results sought for by the practitioners; these results are a reduction in size, impaired constitutional vigor, impaired fertility and fecundity, and a general refinement throughout.

These effects of closebreeding are due to the fact that it operates alike in all characters—good, bad, and indifferent. If, therefore, the character desired is associated with undesirable characters in the animals to be closely mated, e.g., a correct set of pasterns and hocks with under size and low constitutional vigor, and no account of the undesirable characters is taken in the mating, the same force which doubles or intensifies the good characters will act with equal intensity upon the undesirable ones. It is thus that the failures frequently attending the practice of closebreeding may be accounted for.

It should be distinctly understood that closebreeding

neither adds nor subtracts any characters, but merely intensifies both the good and the bad characters already present; therefore, the only safe basis for the practice of closebreeding lies in a knowledge of the ancestry so that the breeder can be sure he is not doubling the weak points—for if there are no weak points he cannot double them.

177. Kinds of Closebreeding.—Closebreeding may vary widely in the degree of its intensity. In their distinction between the different kinds of closebreeding, authors differ somewhat as to the degree of intensity; but the degrees generally accepted are linebreeding, inbreeding, and in-and-inbreeding.

178. Linebreeding.—Linebreeding is the mating of individuals that have a common ancestor but are so far removed that their relationship is less than 50 per cent of the same breeding, e.g., the mating of cousins or of grandparent and grandoffspring.

Linebreeding also varies in its degree of intensity, it being possible to have close linebreeding or diffuse linebreeding. The former is the mating of cousins, grandparent and grandchild, half-uncle and niece, or half-aunt and nephew. The pedigree of Beau Blanchard (Fig. 33) which was the result of using a half-nephew, Beau Mischief, on his half-aunt, Blanche 23d, is a good illustration of close linebreeding. The same pedigree further back furnishes ample illustrations of inbreeding as well as linebreeding.

Diffuse linebreeding is the mating of individuals having a common ancestor but further removed than in the above example. The pedigree of Prince Rupert 29th (Fig. 34) illustrates this type of breeding, he being the product of mating a granddaughter to a great-grandson of Beau Brummel.

As ordinarily practiced, however, linebreeding is the continued breeding back to a certain sire or dam, as in the pedigree of Beau Blanchard (Fig. 33), six of whose eight great-grandparents trace to Anxiety 4th.

In practice, linebreeding, therefore, takes on various forms. It can readily be seen that this would be possible

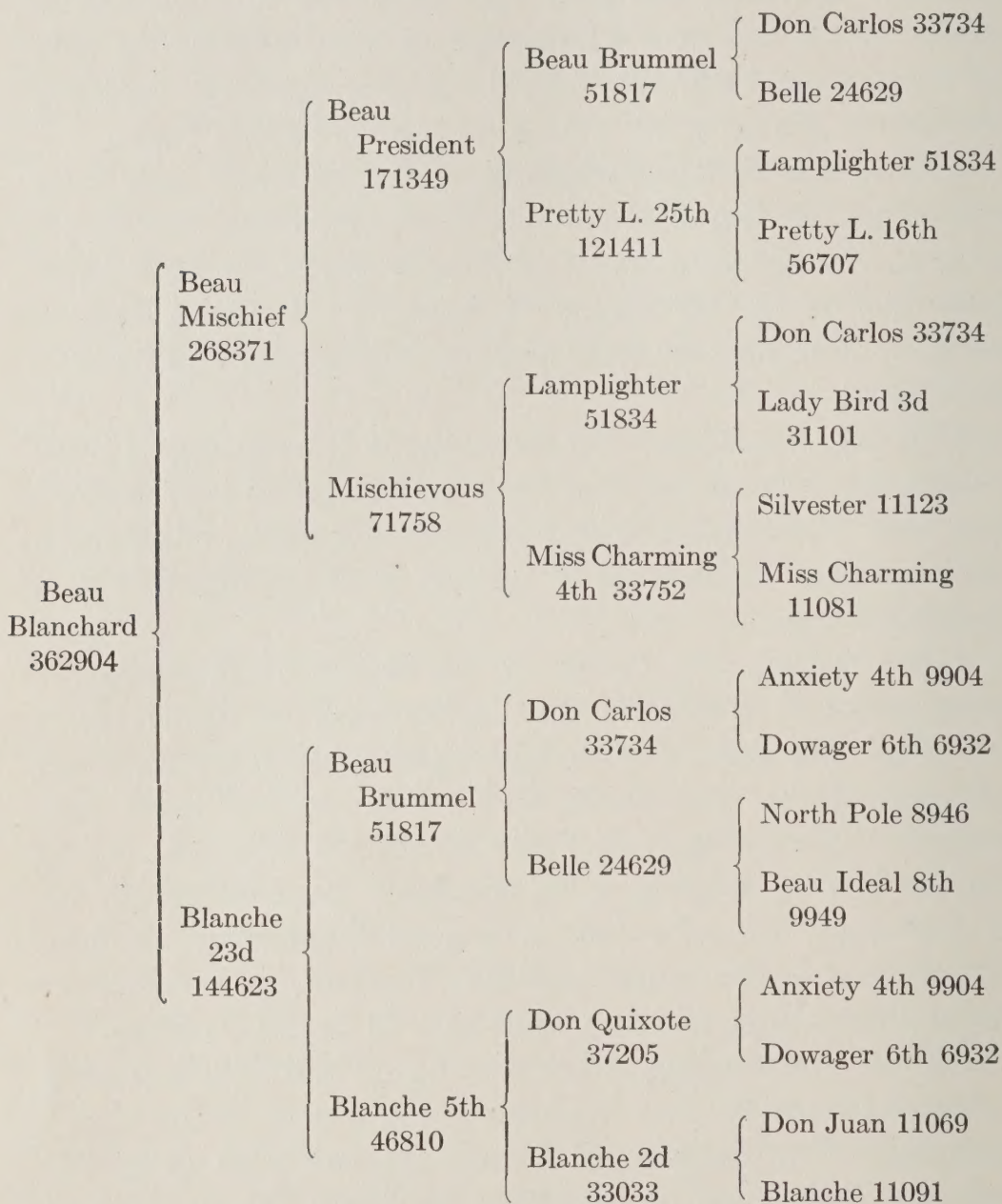


FIG. 33.—Pedigree of Beau Blanchard 362904, an illustration of close linebreeding.

from the matings of cousins, half-cousins, half-uncle and niece, granddaughter and grandsire, double grandsons and granddams, etc. The objective behind any or all forms of

linebreeding is the concentration of certain blood, and the process of selection necessarily leads to the matings of these variously related individuals.

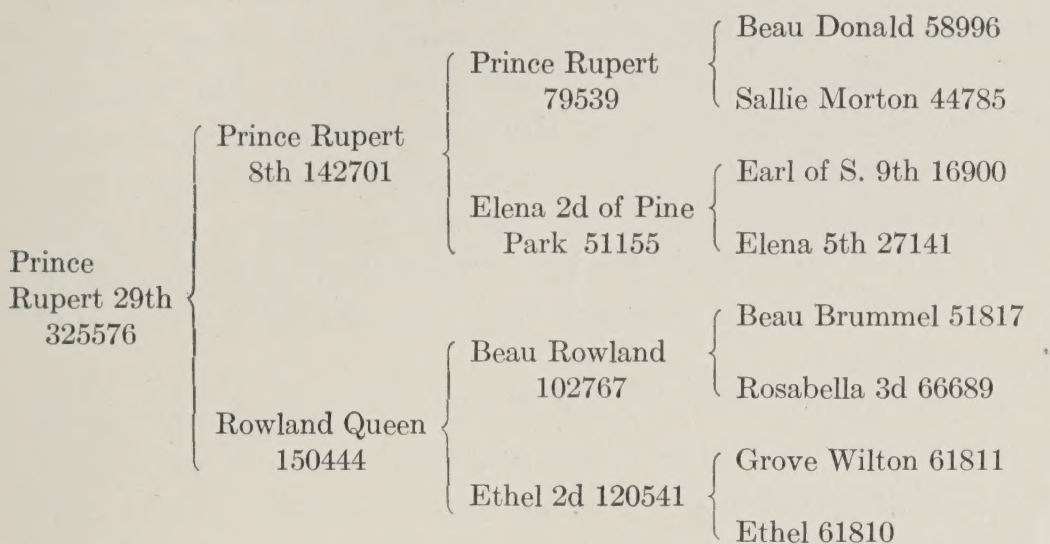


FIG. 34.—Pedigree of Prince Rupert 29th, an illustration of diffuse linebreeding.

179. Inbreeding.—Inbreeding is the mating of individuals possessing 50 per cent or more of the same blood, i.e., (1) full brother and sister, (2) half-brother and sister, (3) sire and daughter, (4) son and dam, (5) double cousins, (6) full uncle and niece and (7) nephew and full aunt. The mating of full brother and sister is the closest possible mating, since they carry 100 per cent of the same breeding. Even though an offspring is carrying only 50 per cent of each parent's breeding and half-brother and sister carry 50 per cent the same breeding, the mating of parent to progeny is closer than that of half-brother to sister; since, in the former case, the resulting individual would be carrying 75 per cent of its ancestry from the one parent who also was its grandparent, while in the latter case the resulting individual would be carrying only 50 per cent of its breeding from one source, namely, its one double grandparent. On a strict percentage basis, the mating of double cousins would be as close as the mating of full brother and sister,

since they have exactly the same grandparents in each case; but in view of the fact that in the former case a generation has elapsed before the concentration is made, which allows possibility for more variations due to the added repassing of the germ plasm, it would not be so close a mating as that of full brother and sister. In a like manner, on a strict percentage basis, the mating of uncle and niece or nephew and aunt would be as close as the mating of parent and offspring; but here too, the passing of the germ plasm is not so direct, thereby introducing possible variations; hence it is not so close, but it should still be regarded as inbreeding.

In the main, the mating of full brother and sister or double cousins would only be practiced where a particular nick has proven to be an exceptionally fortunate one, and it is not put into practice so frequently as the other forms of inbreeding. If there is a desire to preserve as nearly intact as possible the breeding of a particularly good individual, that individual should be mated to its own offspring. All the other forms of inbreeding mentioned serve the same purpose, namely, the concentration of some particular individual's breeding. The pedigrees of Blackcap of Rosengift 2d 265258 and Zara (1228), two notable Aberdeen-Angus cows, represent two of the more popular types of inbreeding (Figs. 35 and 36).

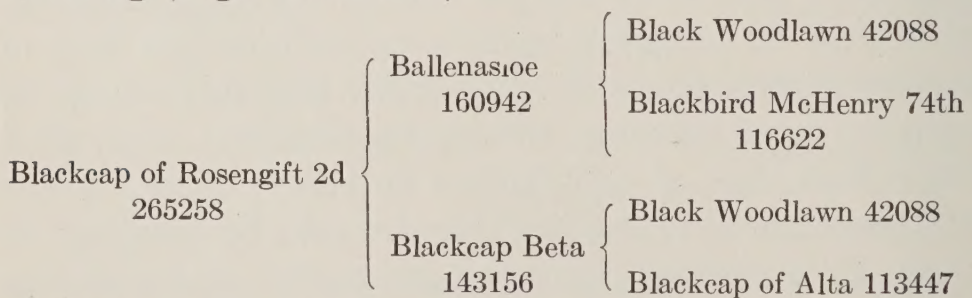


FIG. 35.—The pedigree of Blackcap of Rosengift 2d, an illustration of inbreeding—mating half-brother and sister.

180. In-and-Inbreeding.—In-and-inbreeding is the continued practice of inbreeding with the object of continuing

to concentrate the blood of a certain individual. The pedigrees of the Holstein-Friesian bull, Rag Apple Korndyke 8th 73416 and of the Shorthorn bull, Comet (155) are both

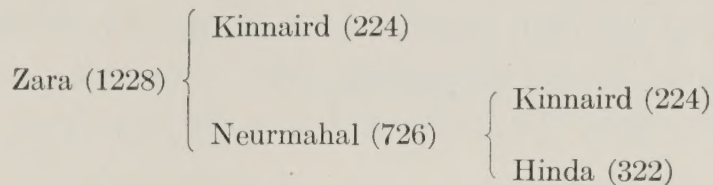


FIG. 36.—The pedigree of Zara (1228), an illustration of inbreeding—mating sire and daughter.

good illustrations of closebreeding carried to the extreme (Figs. 37 and 38).

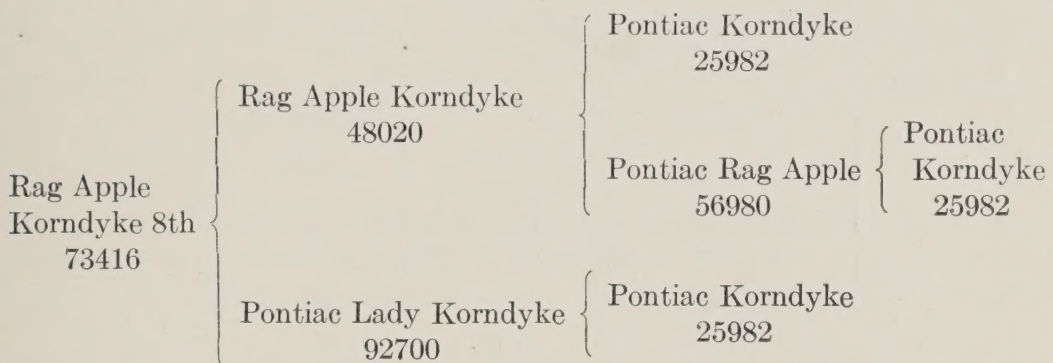


FIG. 37.—The pedigree of Rag Apple Korndyke 8th 73416, an illustration of continued inbreeding.

181. The Practice of Closebreeding.—The earlier breeders practiced in-and-inbreeding to a much greater extent than it is practiced to-day. Practically every breed of livestock was founded, and the type fixed, by closebreeding.

The early Shorthorn breeders, the Colling brothers, Thomas Bates, and the Booths, all practiced closebreeding very extensively. The pedigree (Fig. 38) of the bull, Comet (155), which at public auction sold for \$5000, the record price up to that time, is a good illustration of the continued inbreeding frequently practiced by Charles Colling. Even Amos Cruickshank, who for twenty-five years had combed the British Isles for suitable bulls, was finally forced to

inbreed, using one of his own products, Champion of England (17526) by Lancaster Comet (4663). It is generally held by those most familiar with his work that he would have realized his ambitions earlier had he sooner resorted to the use of his own bulls. At first Mr. Cruickshank was very cautious about inbreeding, but, once satisfied that he was on the right track, he did not deviate from the new

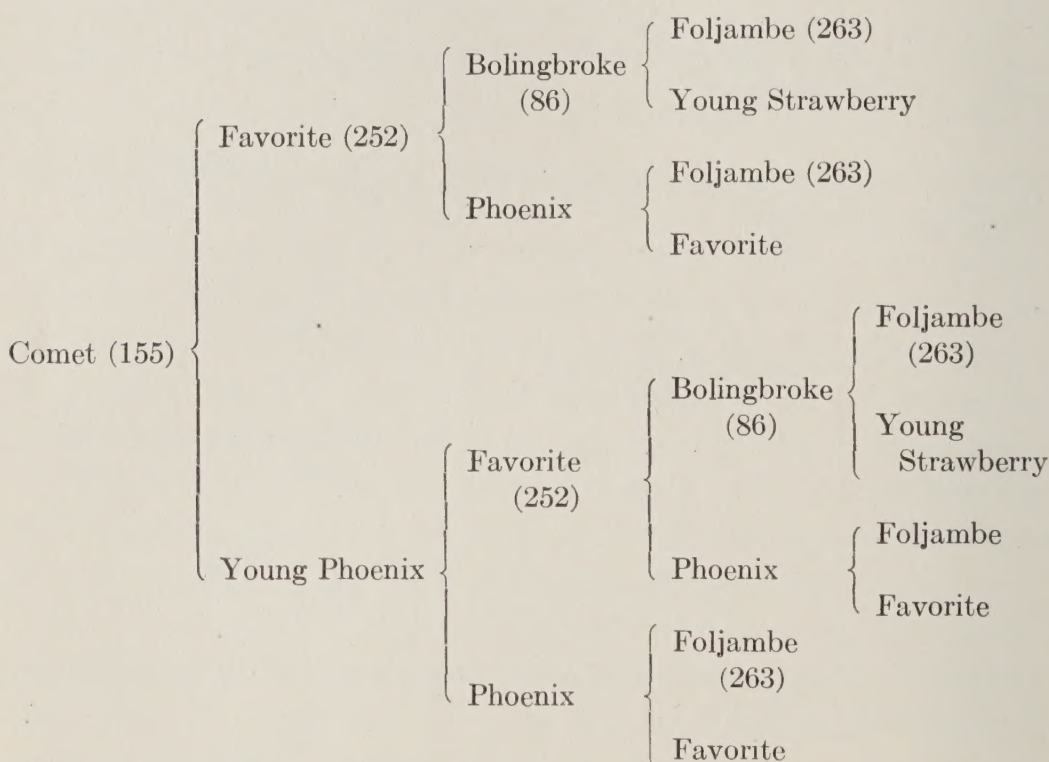


FIG. 38.—The pedigree of Comet (155), an illustration of continued inbreeding.

path, being very careful, however, in his selection, regarding both individuality and ancestry. A good example of his free breeding back to the Champion of England is furnished in the pedigree of Roan Gauntlet (35284) (Fig. 39), which proved to be the most famous of his later-day stock bulls.

American Shorthorn breeders of the past two or three decades, while frequently practicing linebreeding, have inbred but little, as indicated by Table XXI, a tabulation

compiled from a study¹ of the “Record of Shorthorn Prize Winners” published by the American Shorthorn Breeders’ Association and containing the brief pedigrees of the 1260 most prominent American show animals from the early sixties to 1918.

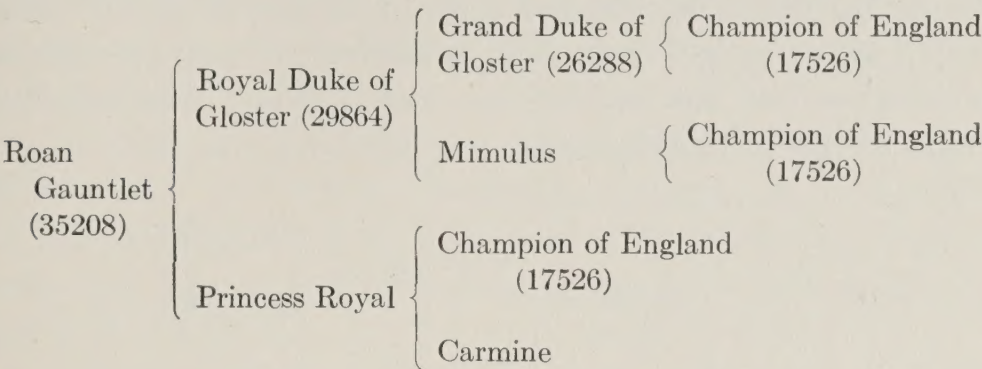


FIG. 39.—The pedigree of Roan Gauntlet, an illustration of inbreeding as practiced by Mr. Cruickshank.

TABLE XXI

NUMBER OF INBRED ANIMALS OF THE 1260 MOST PROMINENT AMERICAN SHORTHORN SHOW ANIMALS UP TO 1918

Result of Mating	Number
Half-brother to half-sister, by same sire	25
Half-brother to half-sister, out of same dam . . .	1
Full brother to full sister	2
Sire to daughter	2
Total inbred	30

Many of the early Hereford breeders, and especially John Price, practiced inbreeding, as did the early Shorthorn men. Gudgell and Simpson, the great American improvers of Herefords, were, like Cruickshank, forced to inbreed. Before resorting to inbreeding and the free use of their own bred bulls—sons and grandsons of Anxiety 4th—they made

¹ Torney, L. J., The Shorthorn World, Nov. 25, 1921.

many futile attempts to introduce new blood by the use of bulls from other herds, and finally they resorted to getting new blood from outcrosses through the dams rather than through the sires. A very good example of the closebreeding finally resorted to—concentrating the blood of Anxiety 4th—is furnished in the pedigree of Sylph 2d 66705 (Fig. 40). This cow had only one grandfather and one great-grandfather and she carried as much Anxiety 4th breeding as one of his own daughters.

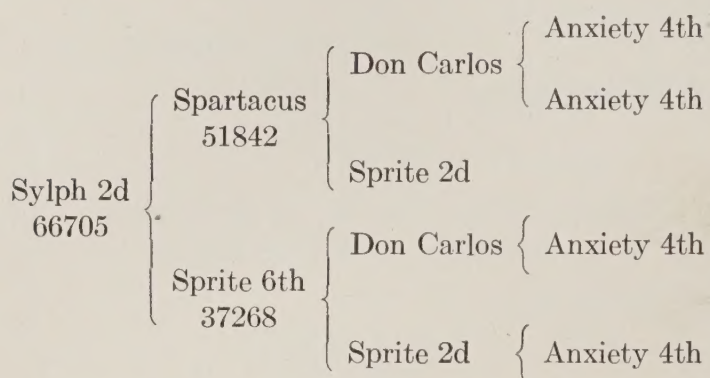


FIG. 40.—The pedigree of Sylph 2d 66705, an illustration of inbreeding as practiced by Gudgell and Simpson.

Present-day Hereford breeders practice linebreeding quite extensively, although some refuse to closebreed even to that degree.

In the early development of the Aberdeen-Angus breed, closebreeding was also freely practiced. For a time, many Aberdeen-Angus breeders linebred to females, following the plan of using only an Erica bull on an Erica female (Erica was the foundress of a famous Aberdeen-Angus tribe) or a Blackbird bull on a Blackbird female. Linebreeding to females is followed with far more difficulty than linebreeding to males, because, as a female cannot produce nearly so many offspring as a male, selection is made difficult. At the present time, however, not many Aberdeen-Angus breeders resort to the above plan.

Closebreeding has been extensively practiced by the

breeders of dairy cattle, especially in the case of Holstein-Friesians.

Among the breeds of horses, the Clydesdales furnish the best example of a breed that has been closely and regularly closebred. The pedigree of Fairholm Footprint 17584, already mentioned (Fig. 32) furnishes a good illustration of the type of breeding that has been quite freely practiced.

In hogs, no breed has been more closely inbred than the Berkshire. The veteran Berkshire breeder, A. J. Lovejoy, of Roscoe, Illinois, is an advocate of closebreeding, and the following extract from a statement made by him is of interest in this regard.²

“ There is no sire of any breed so prepotent as an inbred sire. When we get to the point where we feel the need of outside blood, we mate an imported sow with our best boar, and from this litter we select a boar to use on the get of his own sire from other sows in the herd; that is, we breed this boar on his own half-sisters.”

Sheep breeders have not, on the whole, practiced closebreeding; but McKerrow Farms of Pewaukee, Wisconsin, have, during the past several years, been closebreeding their Shropshires to Imp. Bibby's 133. A good illustration of the type of closebreeding practiced by them is furnished in the pedigree (Fig. 41) of Senator Bibby Type 499886 (Fig. 42), Champion ram at the 1920 International.

The assertion is frequently made that wild animals have been intensely inbred without any bad results. Many close students of nature, however, do not believe that wild animals inbreed to any appreciable extent, their observations being that at a certain age the young animals seem possessed of a wandering instinct which takes them far from their native haunts, and it is their belief that this is nature's method of avoiding closebreeding in wild life.

² Davenport, E., Principles of Breeding, p. 625.

182. Experimental Closebreeding.—A great amount of experimental work on inbreeding laboratory animals has been done, with varying results.

Bos practiced in-and-inbreeding a family of rats for six years, with the following results:

Average size of litter for the first three years.....	7.5
Average size of litter for the last year.....	3.2

A decrease in size amounting to from 8 to 20 per cent in the males also attended the above inbreeding.

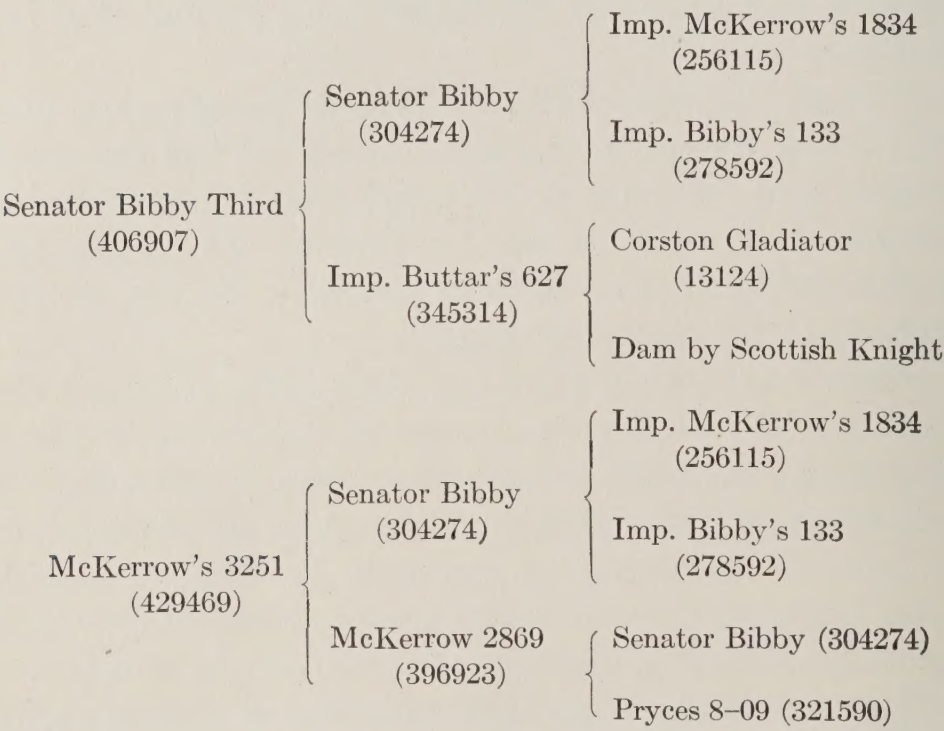


FIG. 41.—The pedigree of Senator Bibby Type 499886, an illustration of closebreeding as practiced by McKerrow Farms.

Weismann bred a family of rats, consisting originally of six females and three males, for twenty-nine generations, with the following results:

Average size of litter for the first ten generations.....	6.1
Average size of litter for the second ten generations.....	5.6
Average size of litter for the last nine generations.....	4.2

On the other hand, other experiments have shown no tendency toward degeneration, but have even shown improvement regarding both size and vigor. The Bureau of Animal Industry has experimentally inbred guinea-pigs for twenty generations, without any very obvious degeneration. There has, however, been a decline in vigor.³



FIG. 42.—Senator Bibby Type, 1920 International Champion Shropshire ram, the result of closebreeding as practiced by the McKerrow Farms. (*Courtesy McKerrow Farms.*)

183. When to Practice Closebreeding.—While the principles of inbreeding may be studied by means of laboratory animals, it is very difficult to draw definite conclusions from laboratory experiments in regard to the closebreeding of farm animals; we must bear in mind that there is a vast

³ Wright, Sewall, U. S. Dept. Agr. Bul. 1121.

degree of difference between a cow and a mouse, and even though the laws of heredity are the same for all animals, all species may not react to closebreeding in the same way. Numerous data have been gathered on humans, illustrating the dangers of closematings; but here again, it is extremely difficult to draw conclusions that can be interpreted in livestock terms, because humans, with all their mental powers and weaknesses, are undoubtedly far more sensitive to closematings than livestock.

There can be no doubt that closebreeding makes for prepotency; on the other hand, its great weakness is the loss of breeding powers so frequently accompanying it. The Colling brothers, already mentioned, who firmly believed in closebreeding, at one time introduced Galloway blood to improve the fertility of their herd. Thomas Bates, another of the early advocates of closebreeding, is known to have been always on the lookout for new blood. There is a danger in inbreeding which should not be ignored; but the main reason why bad results frequently accompany closebreeding is that the breeder has failed to take stock of the weak points of his individuals. To inbreed medium or inferior stock spells ruin; because it simply doubles, in the progeny, the weakness of the ancestor. This very frequently comes about through the matching of pedigrees.

Some of the old breeders were forced to inbreed, because they were so far in advance of the other breeders of their day that for them to go outside for their breeding stock would have been a step backward. Linebreeding is a sort of compromise. It is made possible to-day because in most breeds we now have so many superior herds, studs, and flocks, many of which are somewhat related. With linebreeding, none of the bad results accompanying inbreeding are obtained, but the main benefits are secured. Line breeding is a safe and sound practice, even in the grade herd. Inbreeding, however, is only for the master breeder—the breeder who possesses animals which are superior individ-

ually to anything obtainable and are known to have an ancestry with no weak points; and who possesses the rare gift of knowing how to mate those individuals so as to get the best from these matings. Too often breeders only consider what will make a "number 1 pedigree" and forget the even more essential thing—the individual.

CHAPTER XIII

CROSSBREEDING

184. Crossbreeding Defined.—The literature on animal breeding is not fully agreed nor clear in the defining of crossbreeding. It is frequently defined as the mating of two purebred individuals of different breeds. The farmer, however, who has for several years used a purebred Duroc-Jersey boar and in consequence has a well graded herd of Duroc-Jersey sows, on which he uses a purebred Poland-China boar, thinks and speaks of it as crossbreeding; and that is what it is, for he is mixing breeds rather than grading. Then again, crossbreeding is defined as the mating of individuals of different breeds or species; this definition covers both the above-mentioned types of crossing and the mating of different species, e.g., ass and horse. But even this is not broad enough in scope; because the breeder of purebreds frequently follows closebreeding for a time and then introduces new blood by mating to an animal of the same breed but of a different bloodline or family; this he speaks of as outcrossing. Domestic animals may be classified biologically according to individual, family, breed, species, and genus; and crossbreeding may be defined as the crossing of families, breeds, or species. Crossbreeding may, therefore, be classified as follows:

- (1) Out crossing, the crossing of families or lines.
- (2) Crossing breeds, which may be of two kinds:
 - a. Crossing grades
 - b. Crossing purebreds.
- (3) Crossing species.

185. The Object of Crossbreeding.—In general, the purpose of crossbreeding is to induce variation. The results of crossbreeding, and generally the primary objectives are an increase of (1) size, (2) vigor, and (3) fertility. The effects of crossbreeding, therefore, are just the opposite of those of closebreeding; the latter tends to restrict variation and its general effect is a decrease in size, vigor, and fertility.

Crossbreds are produced for any of the following uses:

(1) For the production of market animals only, as the famous Shorthorn-Aberdeen-Angus cross.

(2) To make the crossbreds the basis of a new breed, as in the development of the Corriedale, which was evolved by using Lincoln and Leicester rams on Merino ewes.

(3) A single cross to renovate a breed; e.g., the Colling brothers introduced Galloway blood into their Shorthorn herd to revive its fertility.

(4) To get new blood into a closebred family, as Mr. Lovejoy did in his closebred Berkshires (181).

186. Outcrossing.—Outcrossing, the crossing of families or lines of breeding within a breed, is the exact reverse of closebreeding. Breeders are not fully agreed as to whether the best results are attained from closebreeding or outcrossing; and one will experience no difficulty in finding constructive breeders of most breeds practicing either method. Outcrossing may have two different objectives, viz., to introduce new blood into a closebred family, as already mentioned in the case of Mr. Lovejoy's Berkshires (181), or to follow the practice known as "breeding the best to the best."

The latter method, however, may carry the breeder into inbreeding rather than outcrossing, as it did for Bates, Cruickshank, Watson, Gudgell and Simpson, and others, if he reaches the point where his animals are better than can be obtained elsewhere.

The pedigree of Margaret Farmer 512482 (Fig. 43) is a typical example of an outcross and one in which it was the

breeder's intention to introduce an outcross; since the sire, Farmer 426279, is one of the few imported Hereford bulls of recent years.

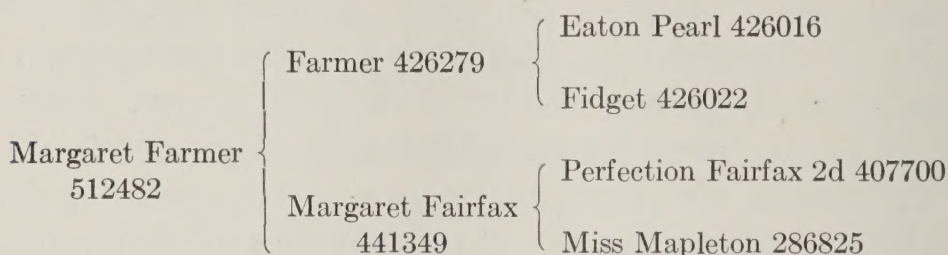


FIG. 43.—Pedigree of Margaret Farmer 512482, an illustration of an outcross.

Outcrossing produces variation, not so pronounced as the crossing of breeds, but enough to make it dangerous for the man with limited means. Linebreeding is a much safer practice; but on the other hand, many of the greatest sires of the various breeds are the result of outcrossing.

187. Crossing Breeds.—In the British Isles, it has been quite a common practice to cross Shorthorns with either Galloway or Aberdeen-Angus, the result being the blue-gray cattle so much favored by the butcher. The crossbred was superior, from a market standpoint, to either of its parents. Many Corn Belt farmers have for some time practiced crossbreeding hogs: formerly they crossed the Poland-China and the Chester-White; now the Duroc-Jersey and the Hampshire are also commonly used on each other or on the other two breeds mentioned. Likewise, range sheepmen use Hampshire, Lincoln, or Cotswold rams on their fine-wooled ewes in order to increase the size and the feeding ability of their lambs.

188. Crossbreds for Breeding.—In the above-mentioned cases, the crossbreds are intended for market purposes. In such cases crossbreeding works well, for the offspring are usually an improvement on either of their parents; the difficulty arises when the crossbreds are used for breeding purposes, because they do not breed true. Many breeders, when crossing, retain the old graded females and sell all

the crossbreds; others operate on a large enough scale to use more than one sire, in which case they keep up the graded herd with a sire of that breed while the crossbreds are marketed. If this is done all is well; but more frequently, and to the detriment of the breeder, crossbreds are retained for breeding purposes and the next sire purchased is frequently of still another breed. This is continued until the herd shows the representative markings of every known breed of that species.

The big objection to crossbreeding lies in the fact that the breeding stock is not being improved, and its improvement is one of the great needs on our American farms today.

189. A Single Cross for Renovation.—Both the Colling brothers and Thomas Bates were advocates of closebreeding, but at one time they found it necessary to resort to a cross of Galloway blood to restore the fertility of their herds. Fortunately, however, breeders of to-day—of the older and more popular breeds—do not find it necessary to resort to such an extreme method of restoring the fertility of their herds; for they can usually find breeding stock of their own breed in sufficient numbers to draw upon. Most breeders to-day are watching very closely for a decrease in fertility and they have found they can guard against it very well from within the breed by selection and occasionally using “new blood”—the introduction of an outcross—if necessary. The latter method, outcrossing, is quite frequently employed to renovate a closebred family.

190. New Breeds by Crossing.—Many new breeds of stock have been developed by crossbreeding. The Oxford Down breed of sheep is the result of crossing Cotswolds, Hampshire Downs and Southdowns, followed by nearly a century of selection. The crossing was started about 1833 and the breed was first recognized as a breed in 1862. More recently, we have the Corriedale, developed in New Zealand by crossing Lincoln and Leicester rams on Merino ewes; and the Columbia, developed by the United States

Department of Agriculture, and founded upon a cross of the Lincoln and Rambouillet. In both cases, persistent selection and culling has been necessary.

191. Crossbreeding Species.—Species are frequently crossed, the object usually being to obtain a commercial animal more useful for special purposes.

The mule is one of the best known examples of this type of cross, being obtained by using a jack on a mare. The mule, or hybrid, is strictly a hybrid and resembles neither of its parents. In Southern climates, it is the favorite work animal, being more resistant to heat and disease than the horse; it also lives longer, and owners maintain that it will duplicate the work of the horse on less feed. On the other hand, it is larger and more fully muscled than the ass, and hence is a better draft animal.

192. Breeding Powers of the Mule.—There is an old Missourian saying that, "The mule has no pride of ancestry or hope of posterity." Both practical and scientific men have, for the most part, considered the mule infertile; and the few reported cases of fertility have given rise to considerable controversy regarding their authenticity. At last, however, it has been definitely demonstrated that it is possible for the mule to reproduce itself. L. T. Branham, of Montalla, Texas, in the summer of 1920, reported the ownership of a fertile mare mule, she having produced a living foal in 1920 to the service of a jack. W. L. Stangel, of the Texas Agricultural College, visited Mr. Branham's farm and secured the loan of the mule and her foal for experimental purposes, at the same time securing affidavits from the owner and his neighbors certifying the foaling of the mule colt.¹ She was bred to a jack during the summer of 1921, but failed to settle in foal. On October 25, 1922, she was bred to a saddle stallion, and on September 26, 1923, she foaled a living stallion colt. At this time the mare

¹ Stangel, W. L., *The Breeders' Gazette*, Jan. 17, 1924.

mule was twenty-two years old and her first foal was three (Fig. 44).

The above-mentioned case is undoubtedly authentic and has demonstrated beyond question the possibility of the mule's fertility. Yet, it is certain that the large majority



FIG. 44.—A mare mule that bred. The mare mule at the right is the dam of the three-year-old mule and two-weeks' old colt at the left. (*Courtesy Texas A. & M. College.*)

of mules are infertile. The known physiological reasons for the mule's usual infertility are as follows:

(1) Most of the studies ² of the generative organs of the mule have been conducted on the male, in which it was found (1) that the tubules were greatly reduced in diameter as compared with those of a stallion of the same age; (2) that many of the Sertoli cells and spermatogonia were degenerative; and (3) that many leucocytes, which apparently play a part in the above-mentioned degeneration, were present.

² Iwanoff, E., *Biol. Cent.* 25: 789-804.

(2) The second physiological reason for the infertility of the mule may be stated thus: the mare has 38 chromosomes in a cell, and the ass has 65; presumably, therefore, the male mule would be produced from a fertilized egg containing 51 chromosomes, 19 of which were obtained from the mare and 32 from the ass, and the female mule from one containing 52, 19 of which were derived from the mare and 33 from the ass.³ It is known that during maturation the chromosomes line up in pairs and then divide. In this case, the regular order of maturation would give

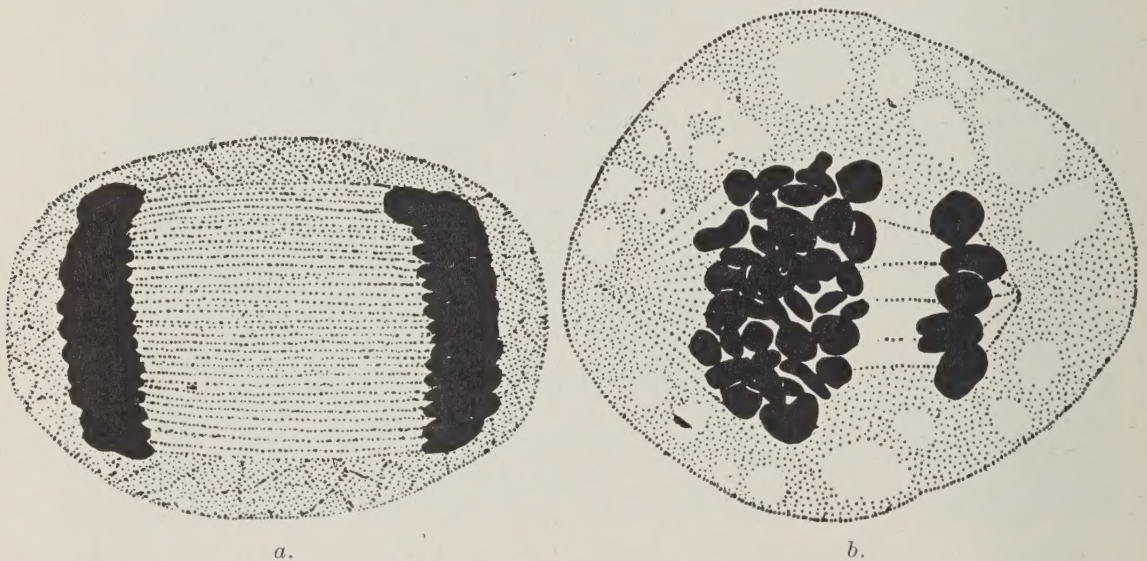


FIG. 45.—Abnormal chromosome reduction during spermatogenesis of the mule.

a, Normal reduction of a perfect cell. *b*, Abnormal reduction in the male mule.

(After Wodsdalek, *Biol. Bul.* XXX.)

place to disorder, because only 19 of the ass type of chromosomes would have mates, the remainder being without mates (Fig. 45). Close microscopic study has shown the disturbance to be so great that the cell is usually destroyed.

(3) Still a third physiological reason for the mule's inability to reproduce is set forth in the results of Ewart's studies,⁴ which show that the sperm cells are capable of

³ Wodsdalek, J. E., *Biol. Bul.* XXX: 40.

⁴ Ewart, Cossar, Penycuick Experiments.

very little action as the tail is only about twice as long as the head, while in the stallion it is eight to ten times as long. This appears more like a case of arrested development than a complete degeneration as reported above.

(4) A fourth physiological reason for questioning the mule's breeding powers is advanced by Habenstreitt. In his studies of the ovaries, he found follicles but no ova.

It would seem, from the preceding studies and the reasons given, that there is little chance for the mule to reproduce; but on the other hand, as has been proven, an occasional fertile mule might be produced.

193. The Hinny.—The hinny is the reciprocal cross of the mule, the result of mating a jennet to a stallion. As commonly reported, the hinny is smaller, finer, and more horse-like than the mule. Some scientists are inclined to doubt that there is any more difference than could be accounted for by individual variation. The hinny has, however, met with very little favor from practical men. If hinnies were as useful as mules, it would be decidedly advantageous to raise them, since mule breeding is a heavy drain on the horse industry, preventing many of our best mares from dropping horse foals which would possess breeding powers and thus improve the quality of our horses. From a biological standpoint, it is rather difficult to see just why there should be any real difference. It would seem that if there were any real difference it must be due to a difference in the development of the foetus, possibly because of its having more room, and perhaps a greater food supply, in the mare. The observation of practical stockmen is that the young, undeveloped female will not produce an offspring that is so large at birth, or that will develop into so large an animal, as will the mature female; if this is the case it would then seem extremely likely that the foetus developing within the mare should be larger and more fully developed than one developing within the jennet.

194. Crossing Bison and Cattle.^{5, 6}—The other hybrid that is of particular interest to North Americans is the one obtained by using the bison bull on domestic cows. The cows often die at calving time, because of the physical difficulties involved in giving birth to the hybrids. In most characters, the hybrids are intermediate between the parents, but in vigor and size they are superior to either. Few male hybrids have been born alive and none of these have proven fertile. Of the 24 hybrid females reported, only 3 were regular breeders and 15 proved barren. The fertile hybrid females carried calves to either a bison or a domestic bull and dropped them with very little trouble. The three-quarter bison is much like the bison and the one-quarter is very much like the domestic bovine. Of the one-quarter blood bison, a little over one-half were regular breeders and of the three-quarter bison, one out of four was barren.

There is practically no hope of developing a breed of the F_1 generation, because of the great difficulty in obtaining the crossbreds and because as yet no male has possessed breeding abilities. There is, however, an attempt being made to establish a breed of the third generation crossbreds, which have been termed "cattalo" by Boyd. The pedigree of Quinto Porto, a fertile hybrid bull, is illustrated in Fig. 46.

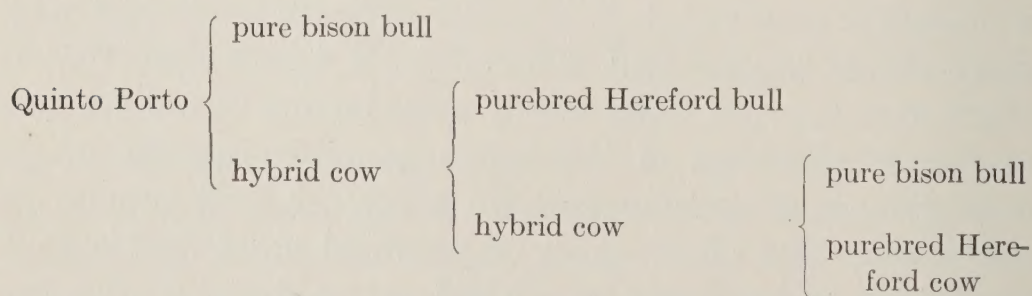


FIG. 46.—Pedigree of a fertile cattalo bull.

In many respects, the cattalo are superior to ordinary cattle; they are less subject to disease, being apparently

⁵ Boyd, Mossom M., *Journal of Heredity*, 1914.

⁶ Goodnight, *Journal of Heredity*, 1914.

immune to Texas fever and blackleg; they do not run from heel flies nor drift in storms; and furthermore, a larger number can be grazed on a given area. It would seem, therefore, that if a breed could be established it would be well suited to the more severe climates of this continent, such as the Canadian North and some sections of the Southwestern states.

195. Other Hybrids.—Another very popular hybrid, especially in Brazil, is obtained by crossing domestic cattle with the brahman (zebu). The cross is very easily made and the hybrids are fertile. A distinct breed has not been developed, although the F_1 generation interbreed freely, because of the ease with which the first cross can be made, and because the development of a distinct breed necessarily calls for many years of selection before the type becomes fixed.

The hybrid is resistant to foot-and-mouth disease, anthrax, and splenetic fever; furthermore, it can withstand the intense heat and insects of the tropics, and is a more productive animal than the original zebu, since it is more meaty and more refined. It is a cross that has a great promise for the Southwestern United States.

Another popular hybrid in the tropics is the zebra-horse. The hybrid is more easily domesticated than its zebra parent, and more resistant to the heat and diseases of the tropics than its horse parent.

In the Canadian North and Alaska, a superior sledge animal is obtained by mating a bitch to a wolf. The mating is very simply made: the bitch, at the time of oestrus, is tied overnight to a tree at some distance from the cabin; the resulting hybrid is termed a "husky." The huskies interbreed with ease; as yet no separate breed has been developed, but at the present time there is a strong movement in the North to develop a distinct breed of superior sledge animals; Fig. 47 is an illustration of Morgan's famous dog team which for three successive years won the

Pas 200-mile derby race. These animals, while mostly dog, contain a strain of wolf.



FIG. 47.—Morgan's famous derby dogs. They carry a strain of wolf.

CHAPTER XIV

GRADING

196. Grading Defined.—Grading is the practical method by which the larger number of our domestic animals are improved. Grading is the mating of a scrub or a grade animal to a purebred—a purebred sire generally being used on scrub or grade females—for the purpose of promoting improvement.

197. Improvement Rapid.—Improvement is made very rapidly by the use of good purebred sires. Since the sire is mated to all the females, it is through him that improvement is most economically made. By the continued use of purebred sires, in a few generations, the stock will have all the appearance, actions, and practical value of purebreds.

Table XXII shows the rapidity with which purebred sires will supplement the unimproved blood with improved.

TABLE XXII

IMPROVEMENT IN BLOOD BY THE USE OF PUREBRED SIRES ON SCRUB DAMS

Generation	Offspring	
	Per Cent Purity	Per Cent Unimproved
1	50	50
2	75	25
3	87.5	12.5
4	93.75	6.25
5	96.87	3.12
6	98.44	1.56
7	99.22	.78

What is still more important is that the economic results closely coincide with the replacement of the unimproved blood, as is illustrated in the following paragraphs.

198. Grading Horses.—So far, no experiments have been conducted to illustrate the exact improvement that can be

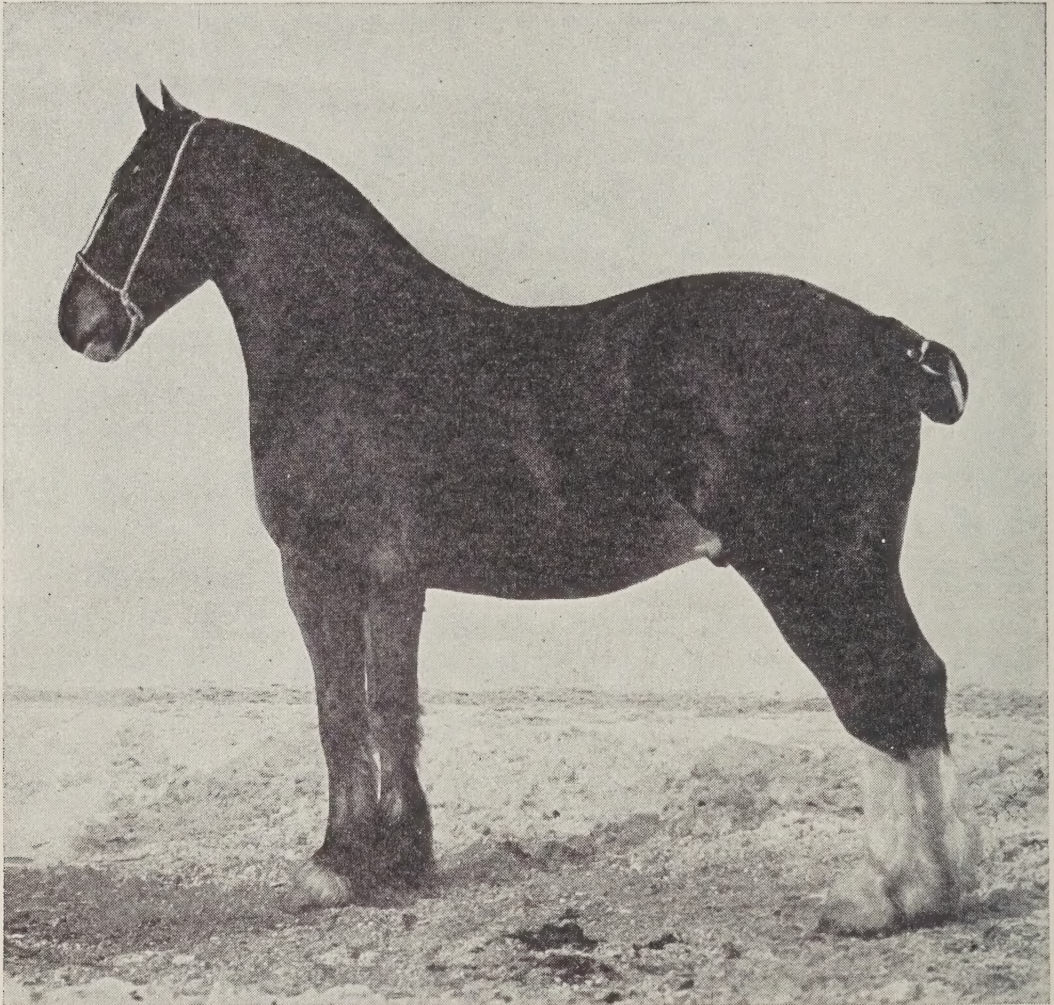


FIG. 48.—Major McFarlane, 1921 and 1923 International Champion gelding, but two generations removed from a Cayuse mare. The result of using good purebred draft stallions.

made on common stock by the use of purebred stallions; but anyone who is familiar with the range has witnessed the rapidity with which good serviceable work horses have been produced by the continued use of good purebred stallions, bronco stock serving as a foundation.

One of the most remarkable illustrations of the improvement a good purebred stallion will make on the common horse stock is to be found in Major McFarlane, alias McFarlane, alias Major (Fig. 48). He is only two generations removed from a little Cayuse mare, but was champion in the grade classes at the 1921 International and was later made a member of the famous Wilson six-horse team.

199. Grading Dairy Cattle.—A breeding experiment to demonstrate the possible improvement in milk production by the use of good purebred dairy bulls on scrub females was started at the Iowa State College in 1907.¹ Table XXIII summarizes the improvement in production that was accomplished in two generations by the use of good purebred dairy sires of the Guernsey, Jersey, and Holstein-Friesians breeds.

TABLE XXIII

IMPROVEMENT IN PRODUCTION BY GRADING WITH PUREBRED DAIRY BULLS
AT THE IOWA STATION

Group	Number of Cows	Number of Lactations	Average Production	
			Milk, Pounds	Fat, Pounds
Scrub dams.....	5	23	3660.2	171.57
First grades.....	5	21	5998.7	261.25
Second grades.....	5	6	8401.9	358.17
Increase in production, 1st generation.....			2338.5	89.68
Increase in production, 2d generation.....			4741.7	186.60
Increase in production, 1st generation.....			64%	52%
Increase in production, 2d generation.....			130%	109%

In two generations, the improvement in production, by the use of good purebred dairy sires, was well over 100 per cent; or, in other words, one of the granddaughters was

¹ McCandlish, Gillette and Kildee, Iowa Bul. 188.

doing more work than two of the old scrub granddams. A large production is of great importance, but economy of production is more important; and in this as well, the improved offspring far outdid the old scrubs, as is illustrated in Table XXIV.

TABLE XXIV

FEED REQUIREMENTS PER 100 POUNDS MILK—LACTATION AND DRY PERIODS CONSIDERED

Group	Grain, Pounds	Legume, Pounds	Non- Legume, Pounds	Silage, Pounds	Soiling, Pounds	Pasture Days	Feed Cost
Scrubs.	49	24	27	133	42	5	2.48
First grades.	46	50	4	103	84	4	2.77
Second grades.	41	46	4	94	76	3	2.48

Not only was there an improvement in production, but there was likewise a most remarkable improvement in type, and the three-quarter bloods took very strongly after the character of purebreds of the blood they carried. To quote McCandlish, Gillette, and Kildee: "This improvement can be noted in the more apparent mammary development with larger and more symmetrical udder, greater capacity of barrel, straightness of topline, especially noticeable over the loin and in the region of the rump, in the quality of the animals as indicated by the more refined head and horns, thinner neck and finer shoulders and finally, the change due to breed type is quite distinct."

In a somewhat similar experiment, conducted by the South Dakota Agricultural College, grade Shorthorn and Hereford cows served as a foundation.² Continuous grading with purebred Guernsey, Jersey, and Holstein-Friesian bulls was also practiced, and Table XXV gives a summary of the

² Olson and Biggar, So. Dak. Bul. 198.

improvement in production wrought in two generations by the use of good dairy sires.

TABLE XXV

IMPROVEMENT IN PRODUCTION BY GRADING WITH PUREBRED DAIRY BULLS
AT THE SOUTH DAKOTA STATION

Group	Number of Cows	Number of Lactations	Average Production	
			Milk, Pounds	Fat, Pounds
Dams.....	7	50	4155.2	170.56
First grade.....	9	28	6707.4	260.06
Second grade.....	7	14	6267.6	267.64
Increase in production, 1st grade.....			2552.2	89.50
Increase in production, 2d grade.....			2112.4	97.08
Increase in production, 1st grade.....			61%	52%
Increase in production, 2d grade.....			51%	57%

A corresponding improvement was made in type. Figure 49 illustrates one of the foundation cows and the gradual improvement in type by the continued use of purebred Jersey bulls for four generations. It will be noted that the little calf, which carries $93\frac{3}{4}$ per cent Jersey blood, would pass as a purebred Jersey.

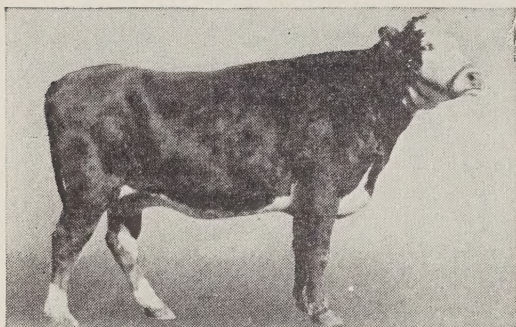
200. Grading Beef Cattle.—One of the most, if not the most elaborate, comprehensive, and far-reaching livestock experiments ever planned was instigated and financed by the late W. R. Nelson, of Kansas City, Missouri, who left in trust a 1755-acre farm in Sni-a-Bar Township, Jackson County, Missouri, and sufficient funds to provide for a thirty-year continuous program of grading with purebred Shorthorn bulls on a foundation of scrub cows.³ The foundation cows consisted of 200 common red cows pur-

³ The W. R. Nelson Plan, Grading up Farm Cattle; and Johnson, Will, The Shorthorn World, Oct. 25, 1921.

chased at the Kansas City stockyards. Some of the cows were in calf at the time, thus giving one crop of scrub calves to be reared and marketed under the same conditions as



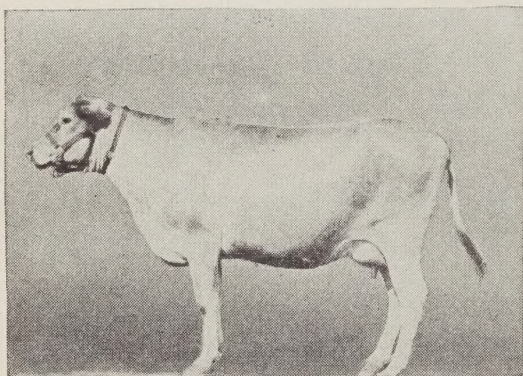
a. Foundation cow.



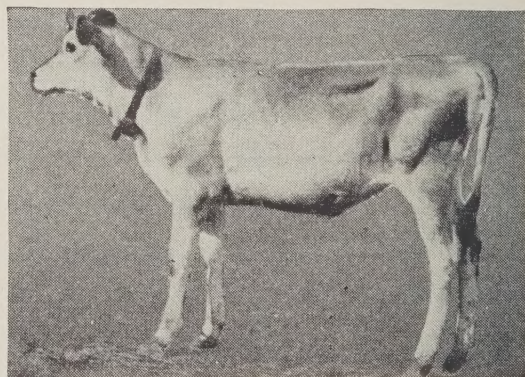
b. First Jersey cross.



c. Second Jersey cross.



d. Third Jersey cross.



e. Fourth Jersey cross.

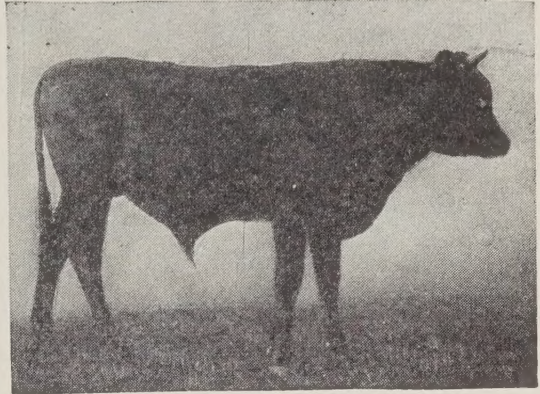
FIG. 49.—Four generations of grading with purebred Jersey bulls. (*Courtesy South Dakota Agricultural College.*)

the later grades. Each year, a field demonstration is held, illustrating to the spectators the results accomplished by the continued use of good sires. Figure 50 illustrates the

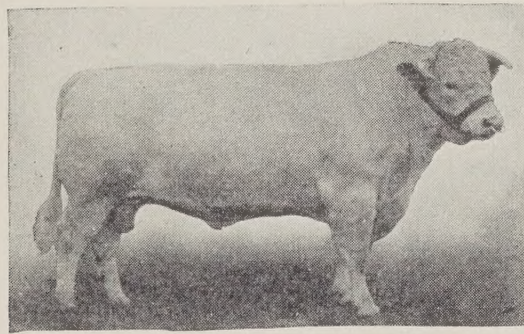
improvement made. Table XXVI summarizes the improvement made from a market standpoint by the use of good purebred sires. In the case of market animals, it is impos-



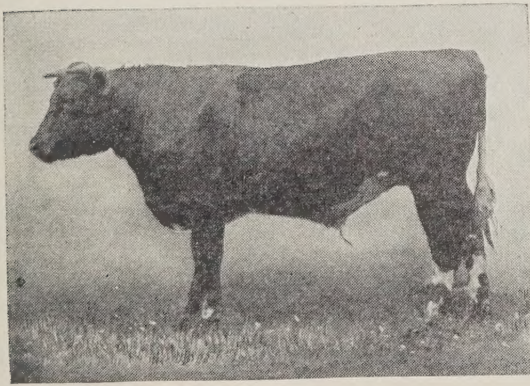
a. Original cow.



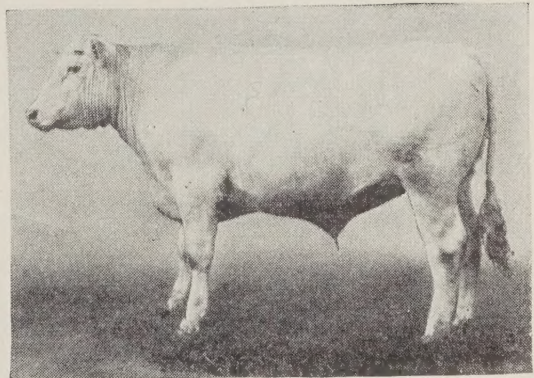
b. Nondescript steer.



c. Type of bull used in grading.



d. First cross steer.



e. Second cross steer.

FIG. 50.—Improvement in beef cattle by grading. (*Courtesy Sni-a-Bar Farms.*)

sible to make direct comparisons of one generation with the other as in dairy cattle for the simple reason that their qualities cannot be reduced to a single set of figures like the

production of dairy cows. Because of this, the price received for each group of steers marketed was compared with the top price brought by other cattle reaching the same market during that same week.

TABLE XXVI

SUMMARY OF GRADING WITH SHORTHORN BULLS AT THE SNI-A-BAR FARMS
UP TO 1921

Breeding	Number	Market Price		Over or Under Top	Price Proportionate to Top
		Top of the Week	Sni-a-Bar Cattle		
Scrub.....	39	9.62	7.88	-1.74	.82
1st cross.....	82	11.57	11.30	-.27	.98
1st and 2d cross..	184	14.84	16.05	+1.21	1.08

201. Grading Sheep.—The Missouri Agricultural College ⁴ purchased 34 Colorado ewes, 17 of which were bred to a purebred Hampshire ram while the 17 others were bred to a scrub ram. The results of this experiment may be summarized as follows:

(1) The lambs sired by the Hampshire ram made 26.6 per cent greater daily gain than those sired by the scrub ram.

(2) For every 100 pounds of gain, the scrub-sired lambs consumed 88.78 pounds of grain, to 52.81 pounds consumed by the purebred-sired lambs.

(3) The purebred-sired lambs sold for \$7.35 per 100 pounds, and the scrub-sired lambs sold for only \$4.50 per 100 pounds.

(4) The higher price procured by the purebred-sired lambs was due to their being broader, thicker fleshed, smoother, and more uniform than the scrub-sired lambs.

⁴ Hackedorn, Howard, Mo. Circular 65.

202. Grading Hogs.—No results of experimental work in hog grading have come to the writer's attention; but work done by the University of Saskatchewan would indicate that the common hog stock of the province can be graded up so as to enter the select bacon market class by a double cross of good purebred bacon-type boars.

203. Grading Chickens.—The farm poultry raised on this continent suffers to a large extent from the failure to use good male birds. Far too frequently, the cockerel that is unfit for the fall market is retained for breeding purposes. Here too, great improvement can be made by the use of good males. A demonstration of this kind, made at the Kansas Agricultural College,⁵ gave the results presented in Table XXVII.

TABLE XXVII

IMPROVEMENT IN EGG PRODUCTION BY GRADING WITH WHITE LEGHORN COCKS

Group	Average Egg Production	Per Cent Increase
Mongrels.....	72.3	
First grades.....	155.9	115
Second grades.....	188.6	160
Third grades.....	192.6	166

While grading is as easily and rapidly done with poultry as any other class of farm animals, yet most poultry experts advise raising standardbred chickens because the time thus saved is a greater consideration than the small amount of capital required to start a small farm flock of standardbred poultry.

204. Advantages of Grading.—Grading is a fairly rapid and a decidedly economical method of improving the far too prevalent scrub stock. For market purposes, high grades may be as useful as purebreds. The scrub sire is

⁵ Lippencott, W. A., Poultry Production, p. 116.

not only a debit to his owner but he is a public nuisance, for even though he be kept at home—which he seldom is—his get are generally shipped to market with the neighbor's good stock and thus they detract from the sale value of the good stock. Recognizing the public menace of scrub sires, some states have passed laws prohibiting the free range of scrub sires, and all should do so. West Virginia has one of the best and most drastic laws in this respect, providing a fine and jail penalty for anyone found guilty of accepting money for the service of a stallion, bull, ram or boar other than registered. Oregon also has a very good scrub bull law; in addition to making it unlawful to allow the scrub bull to run at large and for the owner to accept service fees for the bull's use, it makes unlawful the sale of any but purebred bulls.⁶

205. Drawbacks to Grading.—There are two great drawbacks that often accompany grading work: The first is that so many, after having made a good start with a certain breed, decide in favor of another breed of which they use a sire, after which their fancy carries them to a third and possibly a fourth. When driving through the country it is not out of the ordinary to find herds of cattle carrying the markings of every breed that ever existed. Persistency must accompany grading work if it is to get real results, and far too few of our farmers have learned persistency in their livestock operations.

The second drawback accompanying grading is the strong temptation to retain a good grade male for breeding purposes. The argument often advanced is, "He is as good as a purebred. What do I care about papers?" The fact lost sight of is that it is the purebred breeding he carries that makes him good and that the grade, even though good individually, is not so prepotent as the purebred, because of the inferior blood he carries.

⁶ Sheets, E. W., The American Hereford Journal, Sept. 1, 1920.

CHAPTER XV

SELECTION

206. Importance of Selection.—A breeder's success or failure depends very largely upon his ability to select breeding animals. The primary object of selection is to promote improvement over the past generation. This is accomplished by eliminating all inferior animals and retaining only the best individuals, thus year by year improving the ancestry by selection with a definite objective in mind. The careful and far-seeing breeder is always retaining, for breeding purposes, the animals that are slightly better than those of the past generation. Variation, therefore, furnishes the basis of selection, while character furnishes the unit of selection. Each individual is made up of various characters, or units, each of which must be given due consideration and weight before the selection is made.

207. Selection of Useful Characters.—Every breed has a large number of distinct characters, so many that it makes improvement complicated and consequently slow. Some of these characters are useful ones, while many others are mere fancy points; and in the main, selection should be centered around the useful characters, if the herd or breed is to make rapid improvement. If selection is based upon one or two of the most useful characters, improvement will be exceedingly rapid and noticeable. A most striking example of this is to be found in Holstein-Friesian cattle, the breeders of which, until recent years, largely centered their efforts upon production. In 1880, Aaggie was credited with a world's record of 18,004 pounds of milk in one year; while

in 1920, Segis Pietertje Prospect more than doubled that record, producing 37,381.4 pounds of milk in one year. In 1912, Banostine Belle De Kol made a world's record of 1058 pounds of butterfat in 365 days; and eleven years later, in 1923, 65 cows of the breed are credited with 1000-pound butterfat records and the world's record has been raised to 1349 pounds, by De Kol Plus Segis Dixie.

On the other hand, during the early period of this advancement in production, little attention was paid to type in Holstein-Friesian cattle. Recognizing the importance of type as well as production, Holstein-Friesian breeders have, since about 1915, made one of the greatest efforts ever made by any breed organization to improve the type of their breed. In 1922 a committee of the breed's best authorities was appointed whose task it was to devise ways and means of bringing before the rank and file of their breeders a conception of what constituted "true-type" in a Holstein-Friesian. The plan decided upon was to reduce to canvas and clay the composite bull and cow of the breed, embodying therein the characters sought for in a "true-type" individual. Studies and photographs of many superior individuals were made throughout the year, at the end of which time artists were employed to reproduce compositely, on canvas and in clay, the desired characters possessed by these many individuals. (Figs. 51 and 52.)

Most breeds, however, possess a large number of characters which may be called fancy points, and which in reality act as a check on the improvement of the economic points, because of the necessary sacrifice made on economic points in selecting breeding stock. Such characters as the white belt of the Hampshire hog, the six white points of the Berkshire hog, the spats of the Clydesdale, the white face of the Hereford, and the characteristic upturned horn of the Ayrshire are typical examples of fancy points which in no wise affect the animal's economic value. Any breed that becomes encumbered with many fancy points is bound to have the

improvement of its economic points retarded. On the other hand, but few breeders or real lovers of livestock would be willing to sacrifice all the fancy points of their favorite breed, as these little markings help to lend character and beauty to the individuals possessing them. Furthermore, after a number of generations of selection, they become so firmly fixed that little attention need be paid to them.

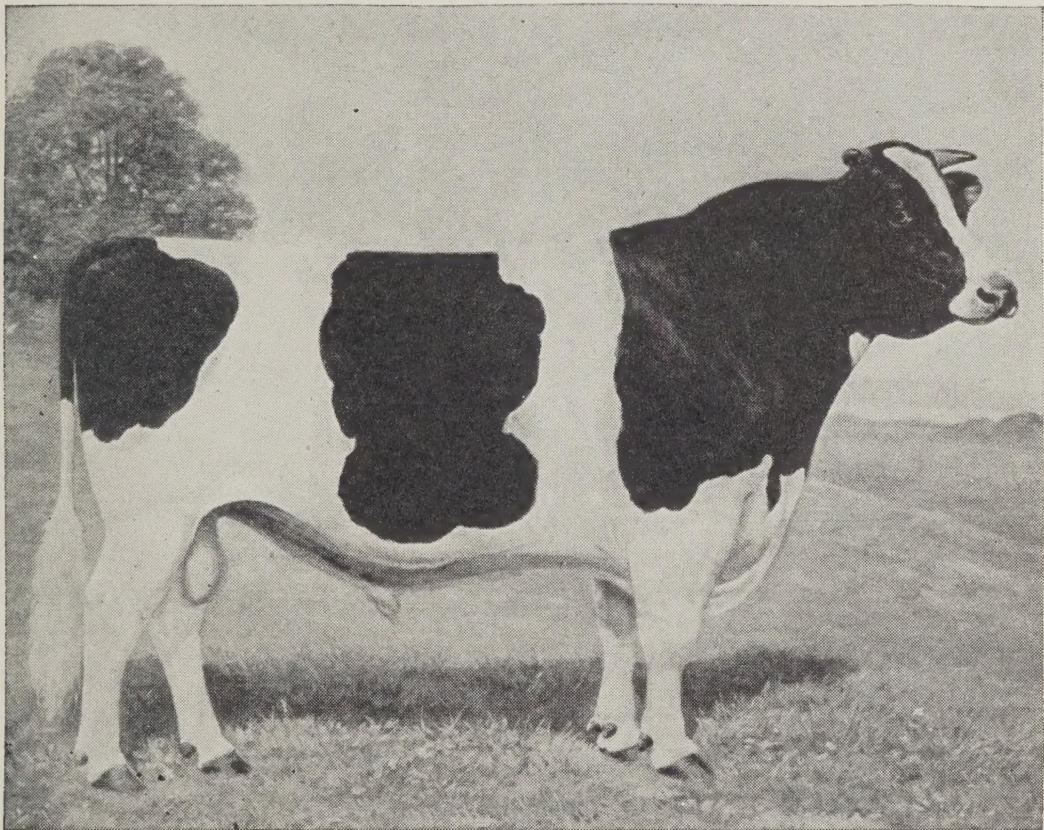


FIG. 51.—True-type Holstein-Friesian bull. (*Courtesy Holstein-Friesian Association of America.*)

Nevertheless, it is well for breeders to keep in mind that utility must come first if a breed is to remain long in favor with the general public; and utility cannot come first if the breed is burdened with many fancy points.

208. Correlated Characters.—Certain useful characters are frequently associated with other characters, which in themselves are only useful because of this association with

the characters primarily sought for. In the case of dairy cattle, experienced dairymen have observed that correct dairy type—large, roomy, spare individuals possessing the triple wedges, long, large and tortuous veins, and capacious udders—is associated with large milk production (Fig. 53); hence the present general recognition of the importance of

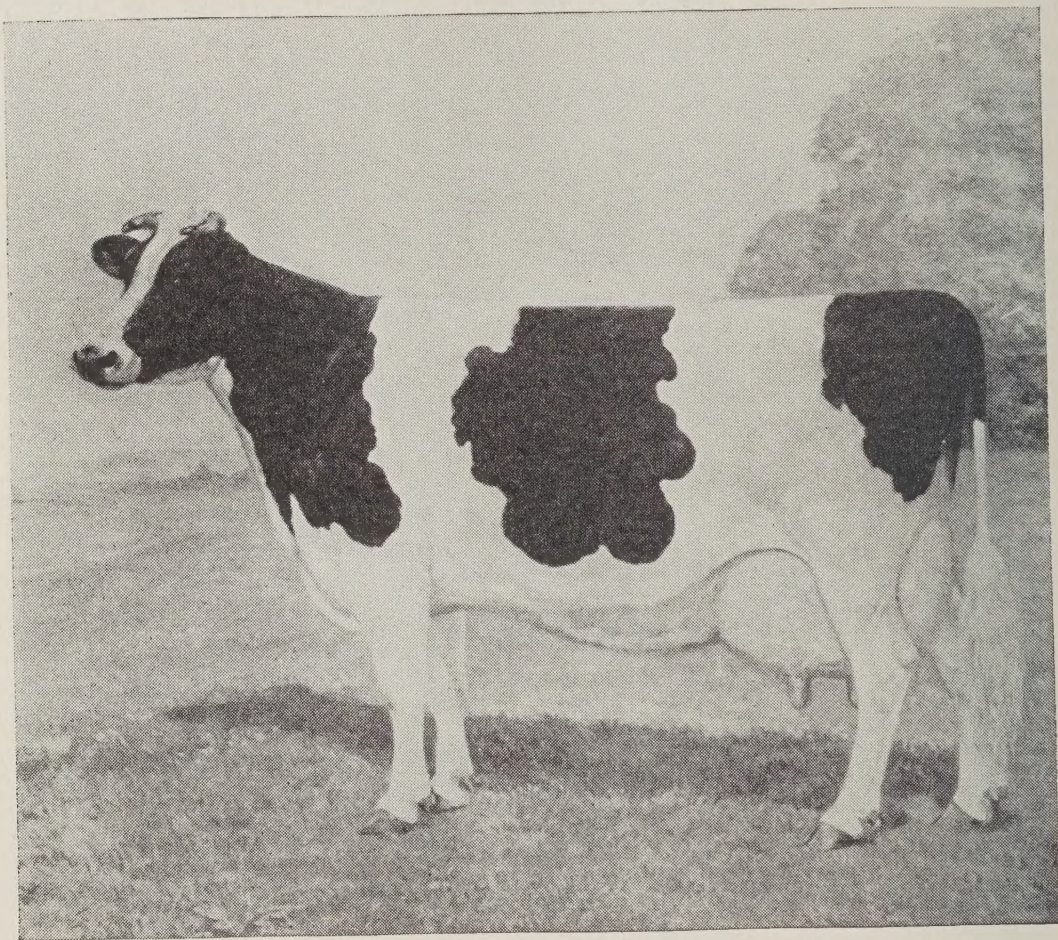


FIG. 52.—True-type Holstein-Friesian cow. (*Courtesy Holstein-Friesian Association of America.*)

correct dairy type. Professor Haecker of Minnesota was one of the pioneers in this work.¹ He divided the university herd into four groups regarding type. The results are presented in Table XXVIII, and plainly demonstrate not only the close correlation between dairy type and production but likewise its close correlation with economy of production.

¹ Haecker, T. L., Minn. Bul. 35.



FIG. 53.—Edna of Mountain View—first in class, 1923 Western Livestock Show; production 16,151.6 lbs. milk, 933.05 lbs. fat—dairy type and production are correlated characters. (*Courtesy The Field Illustrated.*)

TABLE XXVIII

CORRELATION OF DAIRY TYPE AND PRODUCTION

Type	Dry Matter Consumed		
	Daily, per 100 Pounds, Live Weight	Per Pound, B. F.	Feed Cost per Pound, B. F. Cents
Beef.....	1.67	31.3	17.5
Less beef.....	2.10	26.4	15.1
Spare.....	2.30	25.5	14.6
Dairy.....	2.36	21.2	12.1

It has also been noted by feeders that steers with broad short heads and strong muzzles are good feeders, while the

long narrow headed kind are usually shy feeders; hence, they give considerable attention to the head in selecting feeders.

In a like manner there is a distinct correlation between femininity in a female and her breeding powers; and between masculinity in a sire and his prepotency and vigor.

Poultrymen have demonstrated that they can cull flocks very accurately on the basis of correct egg type. In Connecticut ² it was found that culling increased the daily average egg yield on seventy-five poultry farms from 28 to 45½ per cent and reduced the feed bill 40 per cent. Table XXIX summarizes the results of the seventy-five flocks culled.

TABLE XXIX
RESULTS OF CULLING SEVENTY-FIVE FLOCKS

Group	Number of Birds	Egg Yield	
		Daily Average	Per Cent
Before culling.....	7556	2130	28
Birds retained.....	4419	2018	45½
Birds rejected.....	3137	112	3½

All classes of livestock possess a large number of correlated characters. The breeder will do well to study these correlations and select accordingly.

209. Act of Selection.—In the selection of breeding stock there are three main points of consideration, namely (1) the get or produce of the animal, (2) individuality, including form and performance, and (3) pedigree.

210. Breeding Test and Selection.—No truer guide as to an individual's merits as a breeding animal is to be gained than by an inspection of his get or her produce; and if the

² Kirkpatrick, W. F., Profitable Culling and Selective Flock Breeding.

animal in question is of breeding age, that should be the purchaser's first consideration, because the regular getting and producing of good uniform individuals is the business of breeding animals. Not all good individuals of good breeding are good producers, for it frequently happens that a young sire of good individuality and good breeding proves a "sore spot" as a breeding animal. In the Iowa State College dairy herd³ considerable difference was found in the ability of the different sires to sire producers; yet all had been considered good enough in breeding and individuality, by very competent dairymen, to head the college herd. Table XXX gives the summarized results of this work.

Three of the bulls used were valuable as herd improvers; the daughters of these three produced from 15 to 31 per cent more butterfat than did their dams. The daughters of one produced only 3 per cent more milk and fat than did their dams; therefore he cannot be regarded as having worked any marked improvement, but it should be noted that the cows on which he was used produced on the average over 100 pounds more butterfat per year than did the cows on which the other bulls were used. The remaining bull proved a detriment to the herd, since his daughters produced 22 per cent less milk and 18 per cent less fat than did their dams.

Experienced breeders are well aware that the young male fresh from his triumphs in the show yard, is not necessarily a safe bet as a breeding proposition. Therefore the experienced breeder, operating on a fairly large scale, follows the plan of selecting one or two of the most likely youngsters from each year's crop and trying them as sires in a rather limited way. In this way the breeder is able to "spot" the exceptional sire when he appears, and consequently to retain him for regular service. Many illustrations of this point might be mentioned, but one will suffice: the Shorthorn bull, Ringmaster 307894, one of the greatest

³ McCandlish and Winters, Jour. Dairy Sci., Nov., 1920.

TABLE XXX
SUMMARY OF RESULTS WITH DAIRY SIRES USED AT IOWA STATE COLLEGE

Sires	Dams				Daughters				Total Increase in Production		Percentage Increase in Production	
	Num-ber of Cows	Num-ber of Lacta-tions	Average Pro-duction		Num-ber of Cows	Num-ber of Lacta-tions	Average Pro-duction		Milk	Fat	Milk	Fat
			Milk	Fat			Milk	Fat				
<i>Ayrshire</i> Willowmoor Robin Hood 19th.....	3	13	8,932.3	330.44	3	4	9,666.4	432.03	734.1	101.59	8	31
<i>Guernsey</i> Imp. Rouge II's Son.	5	46	6,630.9	286.98	8	14	7,253.5	357.42	622.6	70.44	9	25
<i>Holstein-Friesian</i> Spring Farm King Pontiac 8th.....	6	23	13,051.9	457.50	6	12	13,433.9	470.43	382.0	12.93	3	3
<i>Jersey</i> Fox's Lad O'Dream-wold.....	3	13	7,667.9	356.30	3	7	6,005.0	290.84	-1662.9	-65.46	-22	-18
Pogis 8th of Hood Farm.....	7	46	7,280.4	343.25	9	19	7,504.6	393.65	224.2	50.40	3	15

show bulls of any breed that ever graced the tanbark, as a breeding proposition was not what could be called a real success. On the other hand, Avondale 245144, while good individually, never stood higher than second in his class at the International; but as a sire he proved to be one of the landmarks of his breed. Similar illustrations might be cited from all the breeds, but the above examples show that the best individuals are not always the best breeders; hence, a sire's get or a female's produce is the best indication of his or her breeding ability (Figs. 54 and 55).

211. The Individual and Selection.—While it is true, as above stated, that the best individuals are not always the best breeders, yet, in the main, "like begets like." As there are not enough proven sires to go around, the majority must buy unproven ones; therefore it is necessary to pay strict attention to individuality. No breeder need hope to travel far in his breeding operations unless he is a good judge; and before he can be a good judge he must have an ideal in mind and select according to that ideal. In other words, the individual selected must not only be a good representative of its breed, but the breeder should aim to select so that his herd, flock, or stud will represent uniformity of type.

Not only must the breeder select with an ideal in mind, but he must be balanced in regard to his ideal. He must give the main economic points preference over fancy points, if he would long keep his herd on the road of improvement.

In selecting the individual, there are several points of considerable importance, such as the individual's type, age, constitution, vigor, sex characters, and performance.

212. The Individual and Type.—The individual selected should be of the correct market type, breed type, and, as mentioned above, herd type. Market demand sets market type, and the stock raiser who goes contrary to market demand is bound to be penalized when his stock is marketed. For this he deserves no consideration, because it is the con-

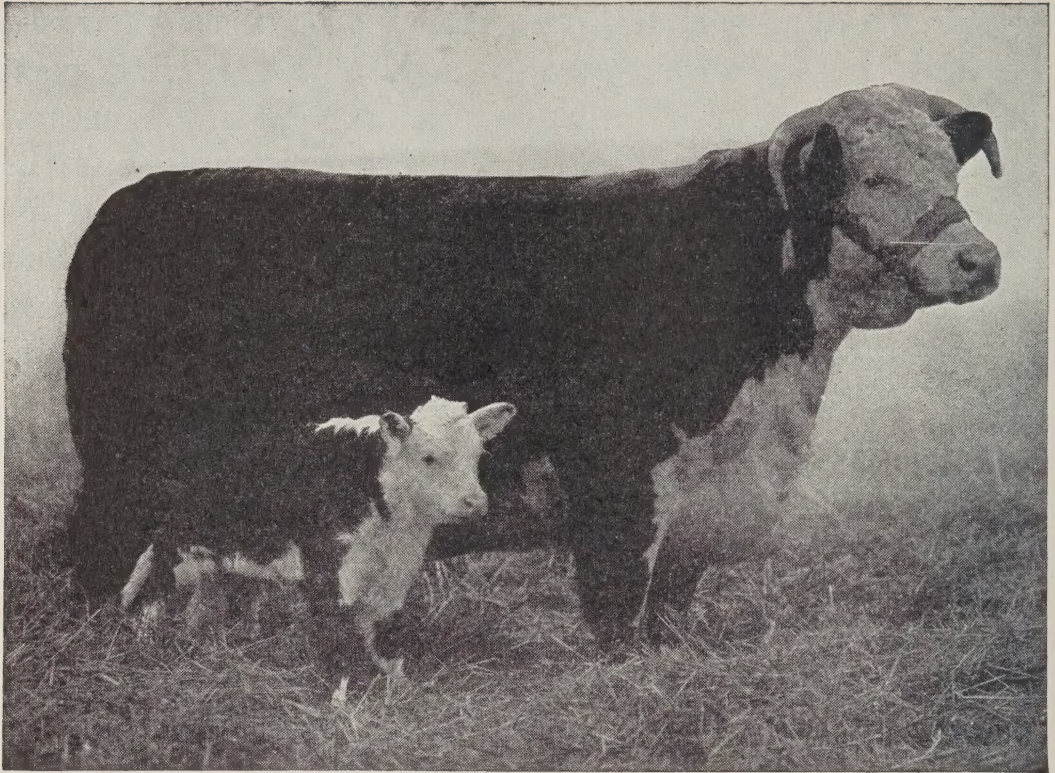


FIG. 54.—Lady Donald 1st and calf. A female's produce is the best indication of her breeding ability. (*Courtesy Warren T. McCray.*)



FIG. 55.—Get of Earl Marshall—First Get of Sire 1922 International—a sire's get is the best indication of his breeding ability. (*Courtesy The Aberdeen-Angus Journal.*)

cern of every man engaged in a business to find out the market requirements and then produce accordingly. Market demands change from time to time, and in consequence market type changes. Some years ago, the market demanded heavy beeves weighing 1700 to 1800 pounds; to-day (1924) there is but a limited demand for this heavy stuff, the great demand being for 800 to 1000 pound steers. To-day, therefore, the popular market type of beef is the baby beef, a calf finished at twelve to eighteen months old, weighing 800 to 1000 pounds, and necessarily of the close-to-the-ground, compact-quality kind.

In a like manner, the market type of hog has changed to meet the market demands. Formerly, when lard was at a premium, the Chicago market wanted thick, fat hogs weighing as much as 300 pounds. In recent years, with a falling off in the demand for lard, the Chicago market wants a "meat hog," one that is stretchy, meaty, not lardy, and ready for the market at approximately 225 pounds live-weight.

As market demand sets market type, so market type sets breed type; every breed must aim, first of all, to embody all the up-to-date points regarding market type in its breed type. Because of this, breed type changes with market type. To-day, the quick-maturing type is in favor in all the beef breeds; and breeders of the lard hogs, formerly so-called, have practically revolutionized the type of their breeds (Figs. 56 and 57).

Herd type should not be in conflict with either market or breed type, but should embody both of them and in addition bear the stamp of the breeder.

213. The Individual's Age.—In the show ring, each animal is presented on his or her individual merits, as they appear at that particular time. The buyer, however, should consider age, making due allowances for either immaturity or old age and hard usage. Very frequently, individuals that appear at a disadvantage for any of these reasons can



FIG. 56.—Joe Orion 2nd, Champion Duroc-Jersey Boar, 1913 International.

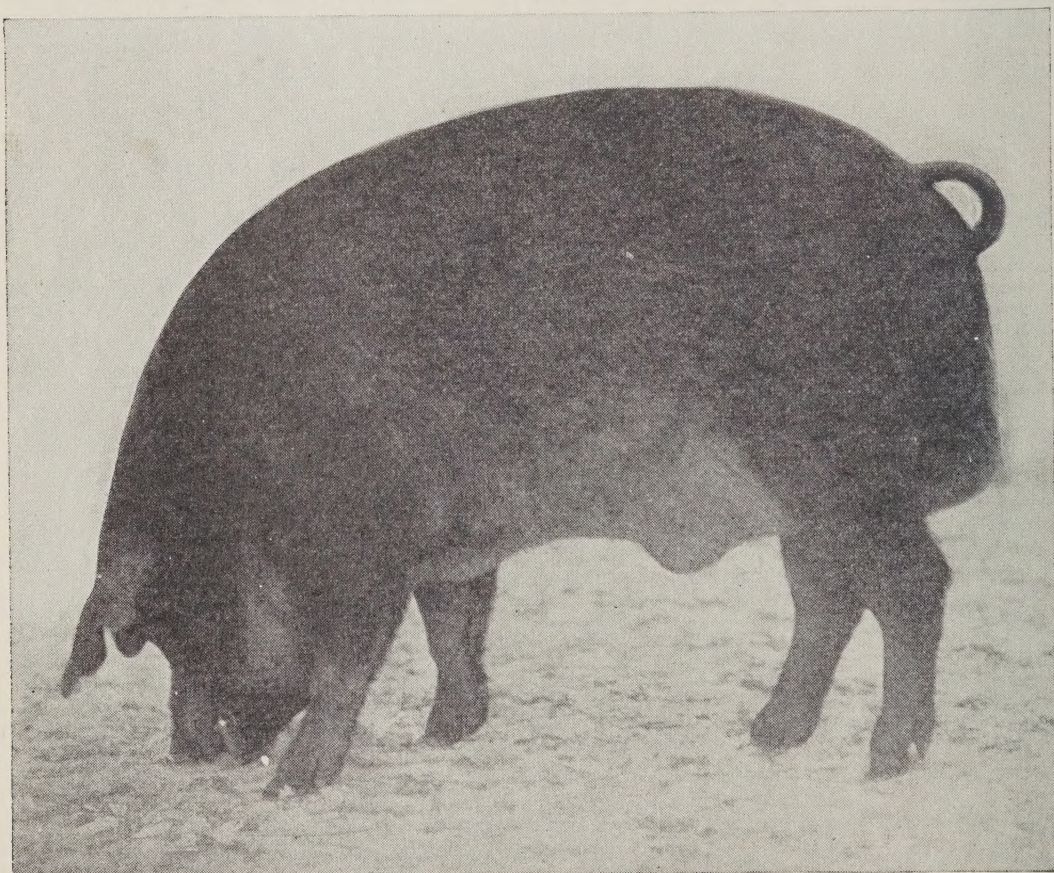


FIG. 57.—Quality Orion King Jr., Grand Champion Duroc-Jersey Boar, 1919 International. Contrast with Fig. 56. (*Courtesy International Livestock Exposition.*)

be purchased more cheaply than those showing to their best advantage. Young animals, at times, have faults that they grow out of, or, on the other hand, they may not have been given as good a chance as they should have had. Older animals very frequently exhibit some of the effects of time, such as a weakening of the top, possibly even some blemish or unsoundness in a horse, gained by accident or extremely hard usage rather than from a faulty conformation. In such a case, due allowance should be made for these factors.

214. The Individual's Constitution.—Strength of constitution and vigor are points which are far too frequently overlooked in selection. It is much more important that a dairy cow make ten good yearly records than one or two phenomenal ones; and she will not, and cannot, do this unless she is strong constitutionally. In a like manner, strength of constitution affects the economic value of other classes of farm animals.

215. The Individual's Sex Characters.—The female possessing refinement and femininity is far more likely to prove a regular breeder than one that is coarse and staggy (Fig. 26). In a like manner, the male showing masculinity, as expressed by a heaviness of the forequarters, a thickening of the neck, bold head, and deep voice, is far more likely to prove a prepotent sire than one in which these qualities are lacking (Fig. 25).

216. The Individual's Performance.—The individual's performance is frequently the best guide as to its real worth individually; i.e., the actual performance of dairy cattle and race horses at the pail and on the track, respectively, is the real index of their worth. It is true that type and performance usually are coexistent; yet it sometimes happens that high-producing dairy cows and fast race horses are not of a good type, in which case they should be used for breeding purposes with extreme care, being mated with animals which will tend to correct their faults in the offspring.

In the case of block animals and draft horses, the show

yard is the best opportunity for performance, and due regard should be given show winnings, as the breed's best authorities are usually employed to pass upon the animal's merits. On the other hand, many good individuals are never shown, and hence, if the prospective buyer is a good judge, he can frequently pick up better buys by selecting superior individuals that have never seen the tanbark.

217. The Pedigree and Selection.—Since an individual cannot be cut off from its ancestors, it is an unsafe practice to purchase an animal for breeding purposes on individual merit only. While it is true that the influence of an ancestor can never be entirely eliminated, yet the further removed the less influence it will exert, by virtue of the fact that with the successive infusions of new blood the per cent of the old decreases to a negligible quantity. The facts, therefore, may be stated thus: All the ancestors exert some influence upon a given animal's individuality and possibilities as a breeder; the more remote the ancestor the more remote the possibility of its influence: as the result of the two last-mentioned facts, the average of the progeny will equal the average of the ancestry; the average of the progeny will, therefore, reveal the average of the ancestry; and the average of the ancestry will, therefore, forecast the average of the progeny. The last-mentioned fact, that the average of the ancestry will forecast the average of the progeny, is the all-essential fact in connection with livestock breeding; that is why the constructive breeders of either purebred or grade stock must and do consider pedigree.

In regard to pedigree value, the following from A. B. Cook ⁴ is of interest:

“ When I buy cattle for my breeding herd I first examine their pedigrees, to see if they have the bloodlines that I want, and to make sure that whatever qualities they possess are inherited and not merely accidental. Then, after I have selected animals whose pedigrees are right, I cull them as

⁴ Breeder's Gazette, Feb. 8, 1923.

to individuals, choosing only those animals which satisfy me in every way with respect to breed character, conformation, and quality."

Many new breeders would do well to defer their initial purchases one year, using that year to familiarize themselves with the history of their chosen breed, and particularly its recent history. This can be done by attending the leading livestock expositions and by studying the advertisements, articles, and show and sale reports contained in the leading livestock journals.

218. Pedigree and Fashion.—At times certain bloodlines within a breed become extremely popular, animals of that breeding selling for high prices. This popularity may be due to the reputation of a certain remote ancestor, in which case animals of that particular breeding are likely to sell for exorbitant prices for a time, their popularity then suddenly declining because the individuals themselves do not merit the accorded popularity. Fashions of this kind practically always occur during times when money is plentiful and the breed is experiencing a boom. One of the greatest fashions of all times was created in the eighties for Shorthorns of the Dutchess breeding, the peak being reached on September 10, 1873, at the New York Mills sale, when 109 head sold for \$381,990, an average of \$3504. Their popularity then suddenly declined, because their individual merit did not warrant exorbitant prices and the popular demand was for animals more beefy in conformation, a type which was better supplied by Scotch breeding.

On the other hand, fashion may rest upon utility, in which case the favored type continues to be popular. Following the decline in popularity of English-bred Shorthorns, Scotch-bred cattle became popular because of their close-to-the-ground, thick-set qualities—the qualities the market demanded in commercial cattle. Scotch breeding is still, thirty-five years later, the most popular, and in recent years certain families within the Scotch cattle have become more

popular than others. A great deal has been written and said, *pro* and *con*, regarding the existence of fashions in livestock; but whether it is right or wrong—which depends entirely upon whether the popularity of the favored animals rests upon the reputation of some ancestor ten or more generations removed or upon the merits of present-day individuals of that breeding—the breeder cannot afford to “load up” on animals of unpopular breeding at popular prices. If a breeder deems that the popularity of certain strains is unwarranted and that he would prefer animals of less popular breeding, then as a business proposition it is to his interest that he secure those animals at prices in keeping with the times.

A good illustration of the way in which animals of popular breeding may outsell others of superior individuality is furnished by Table XXXI, compiled from the 1921 Annual National Shorthorn Congress show and sale. At this show the best offerings of the breed for the year are brought together, and previous to the sale are placed by very competent judges.

TABLE XXXI
HOW BREEDING AFFECTS SALE PRICES

Individual	Breeding	Award	Price
Roan Goods.....	Scotched topped.	Champion female.....	\$900
Lodi Jealousy.....	Jealousy Family..	Not Reported *.....	925
Chenoweth Clara.....	Clara Family....	Reserved Ch. female..	1450
Maxwalton Lavender 2d	Lavender Family.	Not reported.....	2025
Augusta of M.....	Augusta.....	Not reported.....	2600
Linwood Monarch.....	Mary Family....	Reserved Ch. bull....	1000
Pines Gloster.....	Scotch.....	7th in class.....	1000
Edgcote Victor.....	by Edgcote Toft..	4th in class.....	2550

* Individuals having awards “not reported” were either comparatively far down the line or not placed.

All the animals mentioned in Table XXXI were comparatively young, hence practically untried as breeders.

Some of the differences between their prices and show awards might be accounted for by the fact that not all were in show condition; but the greatest amount must be accredited to differences in breeding.

The breeder should use due care before being guided by the extreme popularity of certain lines of breeding; he must decide whether the popularity rests upon true merit or upon a passing fancy. If he conceives it to be but a passing fancy, then it is his business to buy animals of other breeding at current prices for individuals of that breeding; and he can only be in a position to do this after having devoted a certain amount of study to show and sale reports.

219. Pedigree Judging.—The points to consider in judging the merits of a pedigree are: (1) the merits of each ancestor mentioned, but more especially those of the three top-cross sires, (2) the individual's family, and (3) the breeders mentioned.

To properly rate the merits of the animals mentioned, one must be a close student of the breed's history, especially of its recent history, which is not to be learned by text book study but from the breed's sale and show reports.

Certain breeds have families, some of which become more popular than others. Much has been written against this favoritism of families, but nevertheless it exists and in all probability will continue to exist. Therefore, as already mentioned, it is a breeder's business to be familiar with that practice, buying as he deems fit, but to be assured that he is not following fashion for fashion's sake, or if not following fashion that he is not paying fashionable prices for unfashionable families.

The names of the breeders mentioned is of value, because breeders of good repute stimulate confidence. Stock bred by certain breeders always sells higher than stock bred by others, because the public has confidence in them, and so in many cases their names continue to add value to a pedigree even though three or four generations removed from

the individual; but the greatest weight should be placed upon the last two or three breeders mentioned.

220. Kinds of Pedigrees.—Two forms of pedigrees are used, known as the extended and the abbreviated forms (Figs. 58 and 59). The former shows all the immediate ancestors, which without doubt are the most important; it tends to emphasize the sires, but in reality all lines contributing to the individual's breeding are given equal emphasis. The abbreviated form, on the other hand, emphasizes the female family to which the animal belongs. In the United States the Shorthorn breeders use the abbreviated form, with footnotes regarding the breeding of the three top-cross sires; while the Hereford, swine, horse, sheep, and dairy breeders use the extended form, which is also used by the Aberdeen-Angus breeders but with the addition of the name of the family to which the individual belongs. In Canada and the British Isles, the abbreviated form is used to a large extent in all classes of stock.

Use of the abbreviated form has been very severely criticized. In justice to this form it should be stated that it emphasizes the breeders, which is a consideration; and if the buyer is well informed on his breed, he will be familiar with the sires mentioned, provided they are of especial merit. On the other hand, even though a breeder is well informed regarding these factors, it is rather difficult, in looking at the abbreviated pedigree of Ebelum of Ballindalloch (Fig. 59), to consider Eris of Harviestoun as representing 50 per cent of the pedigree. In other words, there is always a tendency to overrate the female side of the pedigree, and more especially the individuals seven and eight generations removed. In pedigree rating, Galton's Law is a very good and safe one to bear in mind, with regard to the proper emphasis to be placed on each individual; and the extended form comes closer to recognizing the importance of this great law in animal breeding.

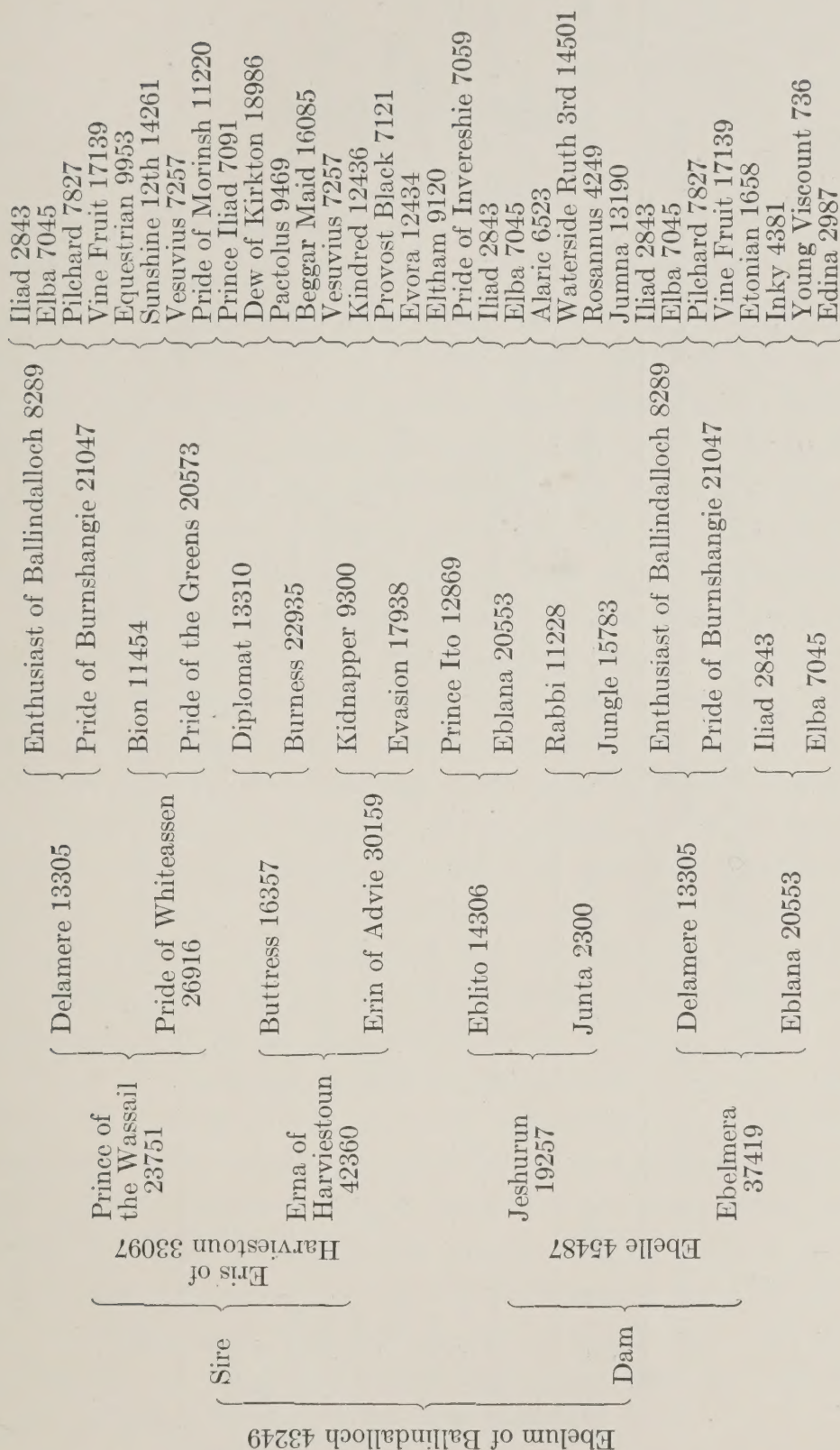


FIG. 58.—Extended pedigree of Ebelum of Ballindalloch.

EBELUM OF BALLINDALLOCH 43249

CALVED 13TH APRIL, 1918; BRED BY SIR GEORGE MACPHERSON GRANT, BART., OF BALLINDALLOCH

Breeders of Dams	Dams	Sires	Breeders of Sires
Sir John M. Grant.....	Ebelle 45487.....	Eris of Harviestoun 33097.....	J. E. Kerr
Sir G. M. Grant.....	Ebelmera 37419.....	by Jeshurun 19257.....	Sir G. M. Grant
Sir G. M. Grant.....	Eblana 20553.....	by Delamere 13305.....	Patrick Chalmers
Sir G. M. Grant.....	Elba 7045.....	by Iliad 2843.....	James Argo
Sir G. M. Grant.....	Edina 2987.....	by Young Viscount 736.....	William Duff
Sir G. M. Grant.....	Enchantress 981.....	by Ballimore 741.....	G. Brown
Earl of Southesk.....	Erica 843.....	by Trojan 402.....	Wm. M'Combie
Hugh Watson.....	Emily 332.....	by Cupbearer 59.....	A. Bowie
Hugh Watson.....	Beauty.....	by Old Jock 1.....	

FIG. 59.—Abbreviated pedigree of Ebelum of Ballindalloch.

CHAPTER XVI

FERTILITY

221. Importance of Fertility.—The function of breeding animals is to regularly perpetuate their kind; therefore, the degree of fertility within a herd, flock, or stud has a very direct bearing upon the profits from that herd, flock, or stud. No breeder, either of commercial or breeding stock, can afford to keep unproductive animals, except in the case of mares which can be used for work. In the case of dairy cattle there is an added loss, the lack of milk production.

Not only are the more fertile females more profitable, since a given number of females will reproduce more offspring which can be marketed, but in addition they enable the constructive breeder, and especially the new breeder, a chance to cull his breeding stock more closely. Assuming that three breeders start in the hog business with one sow each, the average litters of each sow and her descendants being 4, 6, and 8 pigs respectively—one-half of which are, in each case, males—and that the old sows are retained for five years, then the number of females available for breeding purposes each year would be as in Table XXXII.

None of the three would probably want all the females which would be available even before the sixth year was reached; but the owner of sow No. 2 would each year have been able to make a larger turnover in proportion to his capital investment and in proportion to his feed and housing costs than the owner of sow No. 1, while the owner of sow No. 3 would have exceeded either. In addition, the owner of sow No. 3 would each year have been able to cull much more severely than either of the others.

TABLE XXXII

THE EFFECT OF FERTILITY UPON INCREASE OF BREEDING STOCK

Sow Number	1	2	3
Offspring, per litter.....	4	6	8
Breeding females available second year.....	3	4	5
Breeding females available third year.....	9	16	25
Breeding females available fourth year.....	27	64	125
Breeding females available fifth year.....	81	256	625
Breeding females available sixth year.....	243	1024	3125

Fertility is, therefore, one of the important problems confronting the livestock breeder. It is well that he examine closely the factors affecting it, the most important of which are discussed in the succeeding paragraphs.

222. Heredity and Fertility.—Unquestionably, fertility is governed to a large extent by a hereditary force, certain breeds are in general more fertile than others, and certain strains within a breed are more fertile than others.

Coffey ¹ gives the average per cent of lamb crop for several of the sheep breeds, as presented in Table XXXIII.

TABLE XXXIII

BREED A FACTOR IN FERTILITY

Breed	Per Cent Lamb Crop
Southdown...	125-150
Shropshire....	150-175
Hampshire...	119+
Suffolk.....	133

By statistical investigation, Pearson, Lee, and Bramley-Moore ² showed that fecundity in Thoroughbred horses is

¹ Coffey, W. C., Productive Sheep Husbandry.
² Pearson, Lee and Bramley-Moore, Phil. Trans., Vol. 192, 1899.

transmitted from dam to daughter, and that it may be inherited through the male line; the sire transmits to his daughter some of the fertility of his dam. And Rommel and Phillips ³ have demonstrated mathematically that there is a correlation between the prolificacy of mother and daughter in Poland-China sows.

Thus, it is evident that by continued selection a strain more fertile than the average of the breed can be developed. It is a common practice, among observant hog breeders, to select young sows from large litters only, and some shepherds practice retaining for breeding purposes twin ewe lambs and rams. Thus, over several generations, a more fertile strain is developed.

223. Age and Fertility.—Every breeding female rises from infertility to increased fertility, usually reaching the peak early in her full maturity, and then gradually declining until she is again infertile.

A ewe reported by Pearl ⁴ conforms to the above very closely: she had single lambs the first two years, twins the third year, rising to triplets for the next six years, and declining to twins for the following six and to singles for the remaining two years of her fertility.

Studies made at Wisconsin ⁵ and presented in brief in Table XXXIV, show that the age of ewes is a factor influencing the per cent of lamb crop.

TABLE XXXIV

EFFECT OF EWE'S AGE UPON PER CENT OF LAMB CROP

Age of Ewes	2	3	4	5	6	7
Average per cent, lamb crop. . . .	158	174	178	177	178	150

³ Rommel and Phillips, Proc. Amer. Phil. Soc., Vol. 45, 1907.

⁴ Pearl, Science, Vol. 37.

⁵ Carlyle and McConnell, Wis. Bul. 95.

It is quite generally considered that the number of ova ripened during oestrus is the factor governing the per cent of lamb crop, provided the ram used is fertile; but in the same work mentioned above it was found that this was not necessarily the case. Covering a period of six years, yearling rams got, on the average, a 150 per cent lamb crop; while two and three year old rams, each used three years, got an average crop, for the six years, of 180 per cent.

Studies, made by Rommel ⁶ from the records of Poland-China sows during 1902, show that, in general, a sow does not reach the height of her prolificacy until she is at least five years old. A summary of the work is presented in Table XXXV.

TABLE XXXV
EFFECT OF SOW'S AGE UPON SIZE OF LITTERS IN POLAND-CHINA

Age	Number of Sows Studied	Average Sized Litter
1	1520	6.5
2	2047	7.5
3	1157	7.9
4	606	8.3
5	325	8.7

In this study, one reason for the older sows averaging more pigs per litter was no doubt the fact that only those sows proving to be more prolific than the average were retained after the first or second year; but the conclusion that the older sows are more prolific is in keeping with the observations of most practitioners.

224. Age of First Breeding and Fertility.—The age at the time of first breeding undoubtedly has an influence upon the female's fertility, but the degree has not been determined by experimental work. It is well known to

⁶ Rommel, George M., American Breeders' Association, report 19.

stockmen that if the first breeding is delayed too long, conception becomes more difficult and, on the other hand, if the female is bred too early in life she seldom gains full maturity or her full inherent vigor; thus, her life is shortened and her breeding powers are curtailed.

The most desirable age of first breeding is subject to variations dependent to a certain extent upon species, breed, and the feed and care received. In general, individuals of the early-maturing breeds can be bred at an earlier age than those maturing later, and individuals which have been well fed and are well grown can be bred earlier in life than those not so favorably handled.

Studies on the effect of breeding range heifers so as to drop calves as two-year-olds were made by Lantow ⁷ through correspondence with sixty-six ranchers. As a result of asking the question: "Do heifers which produce calves as two-year-olds produce calves at three?" the conclusion drawn was that by breeding to calve at two, a year was lost in over one-half the cases and furthermore, most of the heifers were stunted.

This was followed with the question: "Do you get a higher percentage of calves from heifers bred to calve at three years than at two? If so, how much greater?" Thirty-eight answered "yes," six answering "no"; and the average to the last part of the question was 29 per cent increase.

To the question: "At what age are your heifers bred to calve?," the average given was two years four and one-half months; the only valid excuse given for breeding to calve at two was that the calves were needed at once for ready cash.

Early breeding no doubt decreases the female's breeding powers through retarded development, which is possibly the worst effect of early breeding; therefore, the question

⁷ Lantow, J. L., New Mexico Extension Circular 74.

of when to first breed is closely bound up with the individual's state of nutrition.

225. Nutrition and Fertility.—As noted above, feed has a very important effect upon the individual's degree of fertility. In the studies of Lantow referred to above, the question was asked: "Do heifers bred to calve at two years old, when winter-fed both years, drop calves at three? What is the percentage of the calf crop from these three-year-olds?" The consensus of opinion was that the majority of these three-year-olds would drop calves, the average of their replies being 78.8 per cent, which is about a normal average under range conditions. The above question was followed with: "Do heifers bred to calve at two years old, when not winter-fed either year, drop calves at three years old? What is the percentage of calf crop from these three-year-olds?" The replies to this indicated that such three-year-olds do not usually drop calves, the average given being only 18 per cent. Comparing the answers to this question with the preceding one indicated that a 60 per cent greater calf crop might be expected from three-year-olds, which were first bred to calve as two-year-olds, when winter-fed.

Shepherds have long been aware that "flushing"—getting the ewes in a rising condition previous to breeding—results in a larger lamb crop. The results of experiments run for six years by the United States Department of Agriculture were that "flushed" Southdown ewes produced 198 more lambs per 1000 ewes than nonflushed ones.⁸ Flushing is accomplished by turning to a fresh pasture or by feeding one-fourth to one-half a pound of grain per day. The same practice has been put into effect by many in swine breeding, with equally good results.

Overfeeding is just as detrimental as underfeeding, and it is regrettable that each year a considerable number of our best young females, especially beef heifers, ewes, and

⁸ Flushing Ewes, *The Breeders' Gazette*, Oct. 5, 1922.

mares, are so highly fitted that they never become regular producers.

226. Environment and Fertility.—It is the experience of stockmen that females receiving regular exercise and unstinted fresh air are more likely to raise a full crop of young the following year than those confined to close quarters. The same applies to males: the far too common



FIG. 60.—Regular work is good for the stallion. The two imported stallions, Bonnie Fyvie and Kinleith Footprint, at their daily work for the University of Saskatchewan. (*Courtesy University of Saskatchewan.*)

practice of penning the ram and boar in small pens, and of tying the bull or stallion in the most out-of-the-way corner of the barn, with no exercise and but little care between breeding seasons, is to be deplored; it is destined to result in a decreased get by those males. Both mares and stallions will breed more regularly if given a reasonable amount of work throughout the year (Fig. 60).

Domestication has, in general, resulted in an increased fertility. The domestic sow, bird, and rabbit are all more

fertile than their wild sisters. Mere captivity, on the other hand, generally results in a decided loss of fertility and frequently in complete sterility. Even in his native country and when kept in a good state of nutrition, the elephant seldom breeds in captivity. Lions, tigers, and bears rarely breed in captivity. On the other hand, foxes are now more prolific in captivity than in the wild. They, however, are becoming domesticated (Fig. 28), and their environment is more favorable than that usually accorded to lions, tigers, and bears.

As a general rule, it may be stated that captivity results in a decrease of fertility and domestication in an increase; this, however, has its exceptions as above mentioned—the elephant.

227. Lactation and Fertility.—Prolonged lactation frequently, although not necessarily, exerts an inhibitory influence on oestrus and hence on fertility. It has been the experience of dairymen that cows being hard pushed for records often fail to breed regularly. It is unusual for a sow to breed until her pigs are weaned. Some mares will breed only every two years, undoubtedly being restrained by the period of lactation. Beef breeders frequently experience difficulty in getting cows with calf when they have calves at side; but if the calves are kept in, being allowed to nurse only twice daily, the cows are usually bred with far greater ease. The difference in this case may be due to a lessening of the drain on their systems, and again it may be that with the calves at side their attention is so absorbed that they fail to come in heat.

228. Longevity and Fertility.—Generally, long-lived individuals experience a longer period of fertility than short-lived ones. Therefore, anything—such as early breeding, improper feed supply, unfavorable environment, or overwork—that impairs the female's constitutional strength and bodily development, in consequence shortens her life and as a result lessens her fertility.

229. Inbreeding and Fertility.—The practice of inbreeding, and more especially in-and-inbreeding, as already noted (176–182) is often responsible for decreased fertility. Breeders have found that of all the possible evil effects of inbreeding, decreased fertility is the most detrimental; they have also found that by exercising great care in selection these evil effects, to a large extent, can be overcome.

230. Crossbreeding and Fertility.—Crossbreeding, on the contrary, has just the reverse effect of inbreeding; it acts as an invigorator of fertility. There is a rather common belief that many mares which fail to catch to a stallion will have their fertility revived if bred to a jack. If this should be the case, it can only be accounted for by the possibility that the spermatozoa of the jack are more vigorous and active than those of the stallion, and consequently the jack catches the mare when the stallion failed. Many commercial hog raisers practice crossbreeding; they find that they get larger and stronger litters by so doing.

231. Conformation and Fertility.—While no data have been collected on this point, it is the experience of livestock breeders that roomy females which are refined and feminine (Fig. 26) are more likely to prove regular breeders; and that ewes of that description are more likely to have twins; and sows larger litters.

CHAPTER XVII

STERILITY

232. The Problem of Sterility.—Sterility is that condition of either temporary or permanent infertility so frequently encountered in both males and females. The terms sterility and barrenness are used interchangeably, but the latter is more frequently used to designate sterility of the female.

Since sterility is infertility, the discussions of the two necessarily dovetail into each other. The plan in this work, however, has been to discuss under fertility those factors affecting the degree of fertility, and under sterility those factors that cause either temporary or permanent infertility.

Sterility is found in all classes and breeds of livestock, and it sometimes appears that the better bred the individual the more probability there is of its becoming sterile. That there should be more sterility in well-bred stock than in grades is only natural, because of the unnatural conditions under which some purebreds are kept—excessive condition and lack of exercise—and also because of the greater traffic in purebreds, thereby increasing the likelihood of their encountering accidents and contagious diseases. On the other hand, the statement, frequently made, that purebreds are more subject to sterility than grades, is not founded upon facts and is arrived at because the loss is so much greater that it attracts more attention. In the case of commercial breeding stock, the females may be disposed of at practically full value—although there generally is the

loss of a crop of young—but in the case of purebreds the loss per animal may run into thousands of dollars, and far more serious is the inestimable loss to the breed through future generations, since there is always a scarcity of the superior individuals within every breed.

Beyond question, sterility has been on the increase in recent years; therefore, it is well that the breeder familiarize himself with the more common causes and some of the possible remedies.

233. Causes of Sterility.—More females than males are sterile; but in cases of inability to settle females, the sire as well as the females should receive close examination.

Sterility in the male may be due to inability to perform copulation or inability to produce vital spermatozoa. Marshall¹ classifies the causes of inability to perform the act of copulation as anatomical, physiological, pathological, and psychological. Anatomical causes would include injuries or deformities of the penis. The physiological and pathological causes might be due to incomplete erections or premature ejaculations. The psychological causes include both fear and lack of desire: fear may be caused by muscular or bone diseases that may cause pain in mounting, as spavin, ringbone, diseased muscles of the loin and back, etc.; lack of desire may be due to a variety of causes, e.g., overwork, sexually or physically, improper feed, and environment. Many of the psychological and some of the physiological causes may be relieved through a change of care, feed, and environment.

The mere fact that the male performs the act of copulation is no evidence that he is fertile, for he may not be producing fertile semen. If many females are not becoming settled, this condition should be diagnosed by aid of the microscope, examination being made for the presence of active sperm cells in reasonable numbers.

¹ Marshall, F. H., *Physiology of Reproduction*, p. 645.

234. Sexual Overwork.—The sire may be rendered temporarily sterile by too many services. In this connection, Lewis² reports some interesting work on the stallion. A stallion was permitted one service daily for nine consecutive days; samples of the semen were taken to a laboratory in a warm sterilized receptacle and examined microscopically as to the number of spermatozoa per cubic millimeter of semen. The results of the first, eighth and ninth service are as follows:

First service—131,750 sperm cells per millimeter
Eighth service— 51,480 sperm cells per millimeter
Ninth service— 5,840 sperm cells per millimeter

The sperm cells were also examined as to their vitality by keeping the semen at a temperature of 31 to 35 degrees C., with the following results:

First service—5 per cent alive after 9.5 hours
Third service—0 per cent alive after 6 hours
Sixth service—0 per cent alive after 4 hours
Eighth service—0 per cent alive after 3 hours

The number of services that a male can perform and still retain his procreative abilities will depend to a large extent upon the individual. As a rule, however, two services daily for the stallion or bull, and two services morning and night for the boar or ram are all they should be allowed. In case the females are especially valuable and failure to get them settled entails a heavy loss, it might be well to reduce the above number of services to one-half; while it is true that only one sperm cell is necessary for fertilization, yet the more numerous and the more vital they are, the greater the certainty of settling the females.

Idle, closely confined, and overfed males, especially stallions, often develop the habit of masturbation which, if continued, often leads to sterility. Once the habit is acquired it is difficult to break; the remedy, however, is

² Lewis, Oklahoma Bul. 96.

judicious management, more especially congenial surroundings and sufficient exercise. Persistent cases may be treated by fitting the subject with a shield anterior to the sheath, the shield containing an electric battery so arranged that the subject receives a slight electric shock at the time of erection, but urination is unhindered.

235. Improper Feed and Environment.—Both overfeeding and underfeeding may result in the temporary sterility of both females and males. Carrying breeding animals in show condition too long at a time frequently results in fatty degeneration of the vital organs; also, in the case of females, fat accumulates around and in the Fallopian tubes, thus closing those passages even though the ovaries are still functioning. Rations rich in carbohydrates are the most injurious in this regard, and the practice of some grooms of fitting with sugar is especially bad. Again, overfeeding the bull or ram on silage, which causes guttiness, often produces partial sterility.

On the other hand, underfeeding may be just as detrimental as overfeeding. It has been the experience of commercial cattlemen that after a long, severe winter, accompanied by a shortage of feed, it is more difficult to get cows with calf.

In a similar manner, a lack of exercise and sexual overwork may cause temporary sterility in either male or female.

An interesting case of a bull, pronounced a non-breeder, which was rendered fertile by judicious feed and care, after which he achieved his greatest fame as a sire, is to be found in the Hereford bull, Beau Mischief.³ After two years' trial he was returned to his breeders, Gudgell & Simpson, as a non-breeder. Mousel Brothers, who had long desired Beau Mischief, purchased him for \$150, with the understanding that there was no guarantee as to his breeding ability. The bull had been foundered and was in such a

³ Green, Guy W., *The American Hereford Journal*, June 1, 1922.

disreputable condition that when he arrived at Cambridge, Nebraska, they had him taken out of town after dark through the back alleys to avoid sardonic eyes. His feet were trimmed and he was turned on a hard buffalo grass pasture, which for a short time was supplemented with a light grain ration. After the first season of this treatment he began to breed, and continued to breed until his death seven years later. During these seven years he made "history" for the Hereford breed, many of his sons and daughters selling for sums that ran into four and five figures.

Anderson⁴ reports a somewhat similar case of a Thoroughbred stallion. The stallion was found during the midst of the stud season with apparently no mares settled by him. The trouble proved to be his failure to make a proper discharge; one or two drops of semen caught proved, upon microscopic examination, the germ cells to be normal in number and vigor.

Up to this time he had been receiving a ration of crushed oats and hay, and his exercise was a morning ride of eight or nine miles. His ration was then supplemented with eighteen eggs a day and a hot bran mash at night. His exercise was lessened and the time of breeding delayed until the afternoon, allowing his muscles time to relax. He was soon able to readily serve the mares and a large percentage of the mares then mated to him became pregnant and produced strong foals.

236. Imperfect Copulation.—Undersized males often have difficulty in serving large females, with the result that they deposit the semen close to the vulva and draw most of it off with them, or that they make a false service, only discharging fluid secreted by the glands close to the urethra. Anderson reports a stallion which upon a second service produced a normal number of vital spermatozoa. The remedy in cases of this kind, if possible, is to raise the male's

⁴ Anderson, W. S., Kentucky Bul. 244.

serving ground so that he stands higher than the female and can thus render the service with greater ease.

Then again, imperfect copulation may be due to using oversized males on small females. In this case the strain or even pain of service to the female is often so great that the semen is not retained. Actual injury may be rendered the female by service with too large a male. The use of a breeding crate will relieve the trouble; some males, however, refuse to work efficiently in these, in which case an immature sire should be used.

Some females reject the semen even though the service has been normal. Distracting their attention after service, by walking them about and pinching their backs if they start to strain, often rectifies this condition.

237. Cryptorchids.—A cryptorchid is a male in which the testicles have failed to descend from the abdominal cavity to the scrotum. This condition is most common in the stallion, in which case he is commonly but erroneously called a "ridgling"; a ridgling properly speaking is a male with one testicle removed. In the cryptorchid the development of the testicle has been arrested, this organ generally being undersized and soft; therefore, such a male is usually, but not necessarily, sterile. All cryptorchids should be considered as sterile until proven otherwise, and even then they are not desirable for breeding purposes, because there is a strong likelihood of their transmitting the same condition to their offspring. In the case of purebreds such a transmission might be a heavy loss, and even in grades it is not desirable, for castration is made much more difficult.

238. Obstruction of the Vas Deferens.—Anderson ⁵ reports on a stallion which was rendered sterile by an obstruction of the spermatic cords. The stallion in question had for two years been unable to settle mares; microscopic examination of the semen proved it devoid of spermatozoa. The stallion was castrated and, upon examination of the

⁵ Anderson, W. S., Kentucky Bul. 244.

testicles and cords, it was found that in each cord there was a center of inflammation which had closed the duct so that the sex cells had no outlet to the seminal vesicles. The epididymis of both testes were loaded with pus and dead spermatozoa. A study of the history of the horse failed to show any injury or disease that might have caused this rather unusual condition.

239. Fibroid Degeneration.—Fibroid degeneration is a condition of the testicle in which the fibrous or connective tissue has developed to such an extent that the sperm-forming parts of the glands are destroyed. It is thought that this is probably the most common cause of a male's inability to discharge sperm cells.

240. Presence of Pus Cells.—Anderson ⁶ found, during the season of 1922, six sterile or partially sterile males as the result of pus cells in the semen. The spermatozoa were either dead or sadly lacking in vigor, which condition was attributed to the presence of the pus cells. The pus cells no doubt were due to some center of inflammation along the genito-urinary tract.

241. Hybrids.—As already mentioned, hybrids are frequently sterile. This, however, depends entirely upon the cross, the mule being a good example of one that is generally sterile; the husky, on the other hand, is fertile; and the bison-bovine is fertile in possibly one-half the cases.

242. Free-martins.—Free-martins, already discussed (48) in detail, are usually, although not necessarily, barren.

243. Closure of the Female Genital Organs.—There is a very common belief among horse breeders that mares require "opening," that is, dilation of the os uteri. The too common practice is for the groom to "open the mare," by inserting his finger into the os uteri. Generally the hands are washed in water only, no antiseptic being used, and the fingernails are frequently long and dirty. Dilating the os uteri in this way is far more likely to do harm,

⁶ Anderson, W. L., Kentucky Bul. 244.

through infection, than good. Occasionally, virgin mares may require opening, but nine-tenths of the mares opened would be better off unopened; since dilation of the os uteri occurs naturally and normally in the average mare. If it is deemed necessary to dilate the os uteri, every sanitary precaution should be taken and the act should be performed by a very slow rotary motion of the forefinger.

244. Effect of Exercise before and after Copulation.—Carlson⁷ obtained some very interesting results, over a large number of mares, as to the effect, on the per cent of mares settled, of the manner of taking the mares to the stallion. The results of his tabulations, covering observations on 2395 mares, all of which were farm draft mares whose home environment was very much the same, are presented in Table XXXVI.

TABLE XXXVI
EFFECT OF MANNER OF TAKING MARES TO STALLION UPON PER CENT OF CONCEPTIONS

How Taken to the Stallion	Number of Mares Bred	Number of Foals	Per Cent of Foals
Led by halter.....	427	299	69
Driven double to wagon.....	983	631	64
Driven double to buggy.....	819	477	58
Ridden.....	166	69	41
Total.....	2,395	1,476	61

The conclusions are that the per cent of the conceptions runs inversely to the speed with which the mares are taken to and from the stallion. It is practically certain that mares when ridden would come at the greatest speed; those hitched to buggies, second; those hitched to wagons, third; while those led would come slowest.

⁷ Carlson, G. L., Studies in Horse Breeding, p. 94.

It is questionable whether the speed at which the mares were taken to the stallion had any influence upon the results. The manner of their return after copulation was probably the determining factor, for it is an old Arabian practice to ride mares very hard just before copulation, the contention being that they would then relax and retain more of the semen.

245. Diseased Reproductive Organs.—There are various diseased conditions of the female reproductive organs, such as acidosis (an acid reaction of the vagina), cystic ovaries, and diseased Fallopian tubes, uterus, and os uteri. All of these conditions are frequent after-effects of infectious abortion which is discussed in the following chapter.

246. Treatment of Sterility.—In the normal male or female, there is a natural desire for copulation; hence the use of inciting drugs, in cases of lack of desire, is useless, for it does not remove the cause of the trouble. Cases of that kind can best be treated by placing the individual under a favorable environment, supplying regular exercise and feeding a well-balanced ration of cooling feeds. Many cases of sterility will respond to the above treatment. Daily douching the vagina with boiled water, cooled to blood heat, to which has been added one tablespoon of salt to the gallon, relieves many cases and is the treatment most generally recommended by veterinarians.

Martin ⁸ recommends drenching either bulls or cows with one-fourth ounce of iodide of potassium dissolved in a half pint of water, the dose to be given every second day until it has been given four times. By this time the animal's eyes should water and show foreign matter; the animal's appearance should also indicate general weakness. If these symptoms do not appear, it is recommended that the treatment be repeated a time or two until they do. Following this, a week's interval should be allowed, followed by one or more treatments until the animal appears physi-

⁸ Martin, G. E., *The Breeders' Gazette*, Dec. 22, 1921.

cally well. The animal should not be bred during treatment; and following treatment and previous to breeding it is recommended that the vagina be douched with a mild solution of carbolic acid or ordinary baking soda and water.

CHAPTER XVIII

ABORTION

247. Abortion Defined.—Abortion, although frequently allied with sterility, should not be confused with sterility; abortion is the premature expulsion of the foetus. Abortion is quite generally attributed to three causes, viz., improper rations, injuries, and bacillus abortus.

248. Improper Rations and Abortion.—That rations, even though balanced as to protein and carbohydrate equivalent, may yet be so unsuited to the needs of pregnant females as to cause abortion in cows was demonstrated at the Wisconsin Experiment Station.¹ Growing heifers and breeding cows were fed balanced rations, one of which was made up entirely from the corn plant, a second from the oat, a third from the wheat, and a fourth from a mixture of the three. By the use of by-products, a balanced ration could be obtained from any of the three plants; e.g., the corn ration was made up of 5 pounds of corn meal, 2 of gluten feed, and 7 of corn stover.

Those fed the corn ration developed well themselves, reproduced, and developed healthy calves. Those fed the wheat ration presented the other extreme; the heifers did not develop well themselves, in fact one went blind, and all showed a reduced vitality; and in every case they aborted. The oat-fed heifers fared better in their own development than the wheat-fed ones, but they produced premature, dead, or very weak offspring. Those fed the mixed ration produced living calves, but the offspring were not so strong and vigorous as those produced on the corn ration.

¹ Hart, Steenbock and Humphrey, Wis. Bul. 287 and Research Bul. 49.

The causes of the above-mentioned disorders are that the wheat grain carries a toxic material in the embryo, the wheat protein is an unbalanced protein, and both the wheat and oat rations were lacking in minerals, especially lime. (See 266 and Figs. 61, 62, 63, and 64.)

Without in the least minimizing the gravity of infectious abortion, there is little doubt that a great deal of the abortion trouble experienced, especially in the West and Northwest, where the practice of winter-feeding cattle, horses, and ewes almost exclusively on oat sheaves and wheat-straw, is still quite prevalent, is due to improper feeding during pregnancy.

The above troubles can be avoided, and were avoided at Wisconsin, by the addition of a legume or marsh hay, both of which run high in lime and to a certain extent counteract the toxic substance contained in the wheat embryo. Where this is impossible, 3 to 4 pounds of limestone, steamed bonemeal, wood ashes, or rock phosphate should be added to every 100 pounds of grain fed pregnant females.

249. Injuries and Abortion.—Farmers in general are of the opinion that many cases of abortion are due to injuries caused by falls, kicks, etc.; while most veterinarians are strongly of the opinion that few if any cases of abortion are caused by injuries. Their contention is that in such cases the bacillus abortus was already present, the injury merely accelerating its action, and that other cases were the result of coincidence.

250. Infectious Abortion.²—All is not yet known regarding infectious abortion; but this so-called disease is now generally considered to be in reality a group of diseases affecting the genital tract of cattle. It is closely related to, or is the cause of, (1) sterility, usually due to a diseased

² It is fitting that only the more common aspects of the disease be discussed in a work of this kind; therefore, for a more complete treatment of the subject, the reader is referred to standard veterinary works.

condition of the ovaries, Fallopian tubes, and uterus, (2) premature birth, (3) retained afterbirth, (4) white scours, and (5) calf pneumonia.³

Infectious abortion is caused by an infection of the bacillus abortus, a small, oval-shaped organism about $\frac{1}{37500}$ inch long.

The annual loss to cattlemen due to infectious abortion is enormous. A few years ago, the annual loss in the United States was estimated at \$20,000,000; but in 1918 Hadley⁴ estimated that approximately 8 per cent of all milk cows abort, thereby causing an annual loss in Wisconsin alone of \$3,570,000. Conservative estimates placed on the annual loss in the United States for 1920 were \$75,000,000; and the present (1923) annual loss to the United States and Canada combined is undoubtedly well over \$85,000,000.

251. Susceptibility to Abortion.—All types and breeds of cattle are susceptible to the disease; it is, however, most prevalent in heifers, but adult cows may and do abort, especially those not exposed to the disease until later in life. Many heifers will abort their first calf and then carry the second calf the full period of gestation; a smaller number will abort the second, third, or even fourth time; and some will carry the first calf to full maturity and abort the second. There is a rather common belief that purebred cattle are more subject to the disease than scrubs or grades, but this is not founded upon facts.

252. Symptoms of Infectious Abortion.—The symptoms of infectious abortion are many and varied, but the most common are as follows:

(1) A poor calf crop is always to be regarded with suspicion; and to one visiting a strange herd, the per cent of calf crop is the best index of that herd's infectious abortion problems.

(2) Premature expulsion of the foetus is not always

³ Fitch and Boyd, Minn. Special Bul. 28.

⁴ Hadley, F. B., Wis. Bul. 296.

the result of infectious abortion, but it is safest always to regard it as such until proven otherwise.

(3) The signs or symptoms preceding abortion are swelling of the udder and vulva; a mucous-like, odorless discharge from the vagina; and at times a restiveness, manifest in the individual by a stamping of the hind feet. At times there will be no warning whatever preceding abortion.

(4) Abortion usually occurs during the fifth, sixth, or seventh month of pregnancy, but it may occur unnoticed during the first or second month.

(5) Following abortion, the cow is generally nervous, at times showing signs of heat.

(6) A yellowish-gray, sticky discharge often follows abortion, lasting for about two weeks.

(7) The appetite is generally impaired; owing to irritation of the uterus, the back is often arched, and there is considerable straining.

(8) As a rule, the calf is born dead; if alive, it usually is so weak that it dies shortly.

(9) At times the foetus may become mummified and be retained for a year or so.

(10) A retained afterbirth, even though the calf is well, is reason for suspicion.

(11) Animals that come in heat but fail to conceive are open to suspicion.

(12) Another symptom is failure to breed, which may be due to:

a. A retained corpus luteum (a false corpus luteum). Normally, previous to or shortly following parturition, the corpus luteum is absorbed; and if conception does not follow ovulation, the corpus luteum present at that time loses its yellow color as a result of absorption. Either or both of these conditions are termed "retained corpus luteum." Owing to the retention of this body, an animal will often fail to come in heat, thus leading the owner to believe her safely in calf.

b. Cystic ovaries or Fallopian tubes, or any cystic condition of the genital organs is more than likely to be the result of infectious abortion.

(13) White scours and pneumonia are also signs and effects of infectious abortion.

253. Diagnosis of Infectious Abortion.—The occurrence of several abortions, especially among heifers, is an almost certain indication of infectious abortion; but a more accurate determination may be made either bacteriologically or serologically. Either of these tests can, however, only be made by trained workers.

The bacteriological diagnosis consists of examining under the microscope, for bacillus abortus, smears prepared from the stomach and intestinal contents of the aborted calf, the vaginal discharge, or afterbirth. This is a laborious and rather unsatisfactory method, because of the presence of other germs which may hide the abortion organisms.

Serological determinations (blood tests) are made by the tests known as the agglutination and complement fixation tests. Both are laboratory tests for the bacteriologist. Blood tests have, up to date (1924), been of value in determining the infected individuals and as a means of studying the disease; but not as a means of determining the cows which will abort. The reasons for this are: (1) the period of incubation is only from ten to twenty weeks, therefore an animal may contract and develop the disease after testing and during the same gestation period; (2) animals develop an immunity, and after aborting two or three times they generally become regular breeders even though they carry the disease; and (3) animals when first exposed to the disease are the most apt to abort, as later on they develop an immunity.

254. Dissemination of the Disease.—The germs are especially abundant in the stomach fluids, liver, and lymph glands of aborted or newly born calves; therefore, the aborted foetus and the meconium are sources of contamination.

The bull's genital organs may become infected, and thus through his seminal fluid he may become a distributing source.

Infected cows, however, are the most common means of spreading the disease. Investigations by Schroeder ⁵ show that of all infected cows about 60 per cent at some time have udder infections, the duration of which ranges from a few weeks to seven years. The milk from such cows is, therefore, a further source of disseminating the disease.

Schroeder also found that in a large number of cows with infected udders, the infection entered the uterus during pregnancy, and remained there for a short time following parturition. Any vaginal discharges during or after gestation, as well as the afterbirth, are, therefore, further means of scattering the disease.

255. Channels of Infection.—The channels of infection have been an open question since the discovery of the disease by Bang (1896), who came to the very natural first conclusion that the bull was the chief, if not the only, agent in its transmission. By 1907 he had, however, come to the conclusion that it might be spread from cow to cow without the bull's aid. This latter belief has since come to be accepted as a fact; but many close students of the disease still insist that the bull may transmit the disease, (1) by mechanically carrying it from a diseased cow to a healthy one, and (2) by becoming infected with the disease and thus infecting the cows he serves. In both cases the contention is that the genital organs are an avenue of infection. On the other hand, Schroeder, as the result of extensive research work by the Bureau of Animal Husbandry, arrived at the conclusions that "Clearly, the uninjured sexual cavities of non-pregnant cows do not serve the abortion bacillus as channels of entry." If such is the case, then the bull at the time of service could not directly infect a cow unless her genital organs had an open wound.

⁵ Schroeder, Dr. E. C., *Field Illustrated*, Feb. and March, 1922.

Many investigators had previously held that the digestive tract was the chief avenue of infection; but, so far as the writer could ascertain, Schroeder is the first to arrive at the conclusion that, outside of artificial practices, the ingestion of infected material is the only channel of infection.

The food material may become infected by genital discharges from either infected bulls or cows (cows at the time of service, during pregnancy, or during and following parturition), from foetal membranes and aborted foetus, and from the milk of infected cows, the chief sources of danger being vaginal discharges and aborted foetus. The belief has long been held that the calf may become diseased through the feeding of infected milk, but on this point Schroeder states:

“As far as the bureau’s work has gone, if the calves of abortion infected cows after they are weaned are protected against infection, they are neither more nor less susceptible to abortion disease when they reach maturity than the calves of normal cows, irrespective of whether they did or did not react with abortion tests during the first weeks of their lives.”

256. Prevention and Treatment.—As yet there is no reliable cure for the disease; therefore, treatment consists chiefly in preventing its entrance into the herd and in preventing its spread from animal to animal within the herd. This does not mean that once an animal is infected it is best to leave her recovery to nature, because her recovery may be hastened by certain treatments.

One of the first precautions every breeder should take is in regard to the introduction of the disease into a healthy herd. To one buying from a strange herd, the per cent of calf crop in that herd is one of the best indications of its freedom from abortion disease. If the buyer’s own herd is a valuable one, it would be well to buy the animals subject to the serological test.

Cleanliness is one of the biggest factors in the control

of this disease. It is, therefore, essential that the barn and all utensils be kept clean. A coat of whitewash applied to the walls, ceiling, and woodwork once or twice a year helps considerably in this respect. If abortion is already present in the herd, it is recommended that the reactors be separated from the clean animals until such time as they are free from infection. On many farms this would be extremely difficult and even impossible, and in such cases it is recommended that the diseased animals be placed in one part of the barn or one end of the row and that special precautions be taken that they get no chance to infect material the other cows will eat. This can be prevented to some extent by not allowing the diseased cows access to the others' yard and by daily disinfecting their stalls. The best time for this would be in the morning previous to cleaning the stable, as the attendants, dogs, or cats may easily serve as carriers of the germs. Furthermore, immediately following abortion, the foetus and afterbirth should be removed and burnt or buried. The cow that has aborted should be closely watched for some time for vaginal discharges, and the same disinfected, burnt or both.

It is recommended that the uterus and vagina of aborted cows be douched with one gallon of boiled water, cooled to blood heat, to which has been added two tablespoons of salt. This treatment should be given daily for about ten days, and then twice a week until all discharge ceases. Cows that have aborted should not be rebred until their organs are normal, even though they come in heat.

Before parturition, the cow should be put into a clean, disinfected stall, and her bag, vulva, tail, and thighs washed with warm water and soap. The new-born calf, if alive, should be rubbed dry and put in a clean stall, and his navel disinfected with tincture of iodine. In the past it has largely been recommended, if abortion is present, that the calf be fed boiled milk after the eighth day. Schroeder's results indicate that this is unnecessary.

Cows affected with abortion often retain the afterbirth; this should be removed after two days. The afterbirth can be removed by the layman; but most laymen are too rough and unsanitary in their methods, and wherever possible it should be left to experienced hands. It if comes away with difficulty, flushing the vagina once or twice daily with warm salt water will help to loosen the membranes (263).

In the past it has been recommended that the bull be prevented from carrying the disease from cow to cow by mechanically cleansing his penis and sheath before and after each service. This also, in the light of Schroeder's results, is unnecessary, he recommending that the breeding take place on neutral ground, thus eliminating the chance of spreading the disease by genital discharges getting on material which may later be eaten by healthy animals.

The cows that abort one year often prove to be the most regular breeders later on; therefore, before barren or aborting cows are disposed of, it is well to make certain that they are permanently sterile. If the barren animal is a valuable one, an expert veterinarian should be employed, and if found to be permanently sterile the cow should go to the block.

The treatment for white scours and pneumonia in calves, accomplices of abortion disease, is prevention. The calves should be dropped and kept in clean quarters, and their navels disinfected. If the disease is present the calf should be given some scour serum as soon as dropped.

Treatment of the disease through immunization has attracted a great deal of attention both here and abroad. Immunization is accomplished in two ways, viz., (1) the injection of live abortion germs (a vaccine); (2) the injection of dead abortion germs (a bacterine). The effect of immunization is that the animal is led to build up a resistance. The results of the employment of these two methods by veterinary investigators for the Board of Agriculture of

England are summarized in Table XXXVII. These results would strongly indicate the utter futility of immunization with bacterine, and they would also indicate that treatment with vaccine has very promising results for anyone whose herd is already badly infected with the disease. The danger in this regard lies in introducing the infection. Stockmen would, therefore, do well to go slowly with this until it is indorsed by experiment stations.

TABLE XXXVII

IMMUNIZING CATTLE AGAINST ABORTION

Lots	Animals treated less those which died, were barren or were sold	Aborted		Calved Correctly	
		Number	Per Cent	Number	Per Cent
Vaccine.....	493	32	6.5	461	93.5
Bacterine.....	110	23	2.1	87	79
Not treated....	432	101	23.4	331	76.6

As already mentioned, all is not yet known regarding the disease, but with the large number of trained investigators at work much can be expected in the near future. Therefore, stockmen would do well to watch closely for the latest reports as to control methods.

257. Abortion in Other Stock.—Abortion disease has been found in swine, sheep, and horses, although in none of these has it reached anywhere near the zenith that it has in cattle; therefore, in these animals it has not received nearly so much study but treatment is undoubtedly the same as for cattle.

CHAPTER XIX.

CARE OF THE DAM AND NEW-BORN

258. Before Parturition.—To the normal and average female, oestrus, copulation, gestation, and parturition are but a natural sequence of events, since they are her own response to nature. Therefore, all the normal female requires, during the period of gestation, is nature's own treatment, which is a nutritious ration (palatable, balanced, and containing sufficient minerals) regular exercise, and comfortable quarters. Since gestation usually occurs during the winter months, these simple necessities are not always so easily provided; and it has been the writer's observation, that following a long hard winter in the Northwest when feed has run short and sheep and cattle have thus been forced more to the wheat-straw ration, and when the snow has been so deep that exercise for ewes and sows was made difficult, farmers have exceedingly more trouble with calves being aborted or born dead, lambs born dead or with goiters, and pigs born dead, hairless, or with goiters. As already indicated, it is not always easy to supply these simple requirements so essential to the brood animal's well-being; but, nevertheless, it is not only those animals housed in straw sheds that suffer in this respect; and furthermore, the great bulk of our farmers have not yet learned the great necessity of liberally raising fodder crops, particularly legume hays and ensilage crops.

With the signs of approaching parturition, such as wax on teats, falling away at the hips, and a desire for solitude, the female requires some special attention. The bowels

should be kept open by feeding a laxative feed, as bran or a light dose of salts. The female should be given a clean pen or box stall well supplied with clean bedding; and if the farm has ever experienced trouble from disease, such as abortion or navel ill, the stall should be disinfected, white-wash and sheep dip being especially good for this purpose.

259. Care at Parturition.—There is a natural desire on the female's part to be alone during parturition; and while she, especially if valuable, should be closely watched at this time for any irregularities, the watchers should be very careful not to disturb her.

The cow's uterus dilates much more slowly than the mare's; therefore, more time should be allowed before attempting to help her. If the mare is not making good progress at the end of one-half hour of straining, she is in need of help.

Previous to rendering aid, there are a few things the would-be assistant should do: first, trim and clean the fingernails, wash the hands and arms in water, to which has been added disinfectant, and rub the hands and arms with sweet oil; second, wash the female's vulva; third, keep "cool" and diagnose the trouble before simply pulling at the foetus.

The most usual trouble is mal-presentation. The normal presentation is fore feet and head first, but hind feet first is perfectly all right and does not call for turning. There are numerous varieties of mal-presentations, such as back and loin first and breast and abdomen first; but the most common are forelegs or head bent back.

Examination and the correction of mal-presentations should be made only during rest periods. If the presentation is abnormal, it is well to tie a small piece of rope to any leg that may be protruding, to prevent losing the foetus; then the foetus should be pushed back into the uterus and the abnormality straightened out. In rare instances, the foetus can only be removed by dismembering it and remov-

ing it in parts. This, however, calls for experienced hands.

In other cases, the trouble may only be that of a dry delivery or that the foetus is unusually large. In either of these cases, injecting into the vulva a little sweet oil or cotton-seed oil will ease the delivery. This is especially so with sows or ewes, to which mechanical aid is extremely difficult. A little assistance by means of pulling outward and downward on the foetus will frequently hasten and ease the two last-mentioned troubles. Such aid should be given during labor pains and not during the rest periods.

260. Care of the New-born.—If the new-born animal is not breathing, pat his lungs, pull out his tongue, and wash the mucus out of his nose and mouth. Bathing with hot water (immersing lambs and pigs) followed by vigorous rubbing will often furnish the necessary stimulation.

Foals are often born with the navel cord still unbroken, in which case it should be dismembered by scraping with a disinfected knife. The navel of new born foals, lambs, and calves should be disinfected with tincture of iodine and dusted with boric acid to avoid infections of navel ill and white scours.

Very often, the new-born needs a little help with its first meal. Calves, however, seldom require this assistance; foals, on the other hand, very often need aid in rising and standing when first nursing; and little pigs and lambs may even require spoon or bottle feeding for a few times.

261. Care of the Dam after Parturition.—Even though parturition has been normal and easy, the dam is tired after it; hence, she requires quiet restful surroundings. Generally she is slightly feverish; therefore, a drink—not large nor very cold—should be given about an hour after parturition.

For several days following parturition, the dam should be kept under close scrutiny. Care should be taken that she is not exposed to cold draughts; that she casts her afterbirth; that her bowels are kept open; and that she is

regularly provided with water and feed, feed that is wholesome, light, cooling and slightly laxative. The addition of some bran to the ration is always desirable and bran mash is especially valuable to the mare.

Following normal birth, both the dam and young are soon ready for a little more exercise than a small pen or box stall provides. If it is spring or summer, no better environment and feed can be given than a clean, luxuriant pasture. The pasture provides room, ample exercise, and a clean bed, while grass is one of the best feeds for milk production that can be furnished the nursing dam. If conditions are such that pasture cannot be supplied, then her ration should be nutritious, slightly more nitrogenous than for other animals, and if possible succulent. By taking the above outlined precautions before, at, and after parturition, the percentage of losses may be greatly reduced.

262. Ailments of the New-born.—A few of the more common disorders of the new-born are discussed in the following paragraphs:

(1) *Constipation* is one of the most common disorders of the new-born. Colostrum is a natural purgative, but it frequently happens that much of the colostrum is lost previous to parturition.

The indications of constipation are a dumpish, listless appearance; an elevation of the tail and straining to defecate. If the condition is not relieved, signs of colic become manifest, and the pulse and breathing become quickened.

Prevention is better than a cure; therefore, if milk has been flowing from the dam previous to parturition, it is well to give the new-born a light dose of castor oil or olive oil, and it should be closely watched for signs of constipation. This condition may be relieved by removing the hardened fecal matter with the fingers, or by means of a piece of smooth wire bent double to form a loop. This should be followed by rectal injections of a little raw linseed oil or some warm soapy water, and by a dose of castor oil.

(2) *Diarrhea* is another common disorder of the new-born. Ordinary diarrhea is usually caused by overfeeding, unsanitary feeding utensils, and foul, crowded quarters. The remedy is to remove the cause and to give a light dose of castor oil, powdered chalk, or flour gruel, the dose to be in keeping with the size of the animal.

Infectious diarrhea, or white scours, is a germ disease which is highly fatal and is contracted through the navel at the time of birth. The remedy, therefore, is sanitary precautions; on farms that have experienced trouble of this kind, the precautions should be especially painstaking. The stall should be thoroughly cleaned, disinfected, and white-washed; the dam's udder and posterior parts should be washed with an antiseptic; and the navel of the new-born should be dipped in tincture of iodine.

(3) Joint ill, also called navel ill, is a disease of foals and lambs, the mortality of which runs very high. The disease is probably contracted at birth; therefore the same precautions mentioned in regard to white scours should be taken. Serum and bacterine treatments have experienced only a fair degree of success; they, moreover, should only be used under the direction of a reputable veterinary surgeon.

(4) *Thumps* is a common ailment of young pigs. The pig affected becomes dumpish and in the advanced stages lies on its side, and there is a jerking of the flank. Formerly all cases of thumps were attributed to overfeeding and lack of exercise. It is now known that many, in fact most cases, are the result of an internal parasite which affects the little pig's lungs. The remedy is prevention. This may be attained by using portable hog houses without floors and using new pasture each year; or, if permanent hog houses are used, scrubbing the hog house floor every two weeks during the farrowing season and for the first month following.

(5) *Sore eyes* in lambs are another frequent cause of

trouble. A few drops of silver nitrate solution dropped into the eye each day usually remedies the trouble.

(6) *Pock-like sores* on the lips and nose of young pigs and lambs are frequent causes of trouble. The scabs should be rubbed off, the sores opened, and sheep dip applied.

(7) *Goiter and hairlessness* cause heavy losses of new-born pigs, lambs and calves. The young so affected are usually dropped weak or dead, and they are commonly devoid of hair and have enlarged necks. Experiments have shown that this condition may be avoided by giving the dam a daily dose of two grains of potassium or sodium iodide throughout the gestation period. Apparently the disorder is due to a lack of iodine in the ration, and furthermore it seems to run in districts and farms; therefore, farms having trouble one year will do well to feed as indicated above in succeeding years. In order to render feeding easier, it is well to have the druggist make up a solution of iodine; this can then be sprinkled on the feed. Goiter may often be relieved by daily swabbing the neck with tincture of iodine.

263. Ailments of the Dam.—The most common disorders of the dam are discussed in the following paragraphs:

(1) *Retained afterbirth* is a disorder of cows, as already mentioned (256), frequently accompanying infectious abortion. The afterbirth should, if possible, be removed within forty-eight hours after parturition. The operator should first carefully trim his finger-nails, wash his hands and arms with an antiseptic, and grease them with vaseline or sweet oil. The afterbirth attachments are much like buttons; therefore, they should be detached one by one by passing the thumb between the uterus and the membrane. The operator should use extreme care to be gentle, for the membranes should not be torn. After the membranes are removed, the passages should be irrigated with a lukewarm salt solution which has previously been boiled.

(2) *Eversion of the uterus* (casting the withers) often follows a difficult parturition in cows. Before the uterus is

replaced, if it is protruding far enough to become dirty, it should be carefully washed, to drive out the blood, with cold water, to which has been added carbolic acid in the proportion of one dram of carbolic acid to one quart of water. The uterus is replaced gradually, by means of the closed hand. When replaced it should be held there until the cow stops straining, after which a pair of bull rings put in the vulva will keep it in place, or a harness so arranged that a band passes over the vulva will keep the cow from recasting it. The rear of the cow's stall should also be elevated.

(3) *Milk fever* is a rather common ailment following parturition in dairy cows; the best and heaviest milkers are most liable to attack. The first symptoms are uneasiness, which is followed by a dullness and loss of appetite, until finally the cow lies down and later turns her head to her side. The apparent cause is milking the cow dry during the first few days following parturition. The remedy is to inject air into the udder. Good milk fever outfits are on the market, and every dairyman should have one. If none is at hand, the udder can be pumped up by means of a bicycle pump and a milk tube, or even a small quill if no milk tube is at hand. Each quarter should be filled and then refilled after two or three hours. The cow should be propped up on her brisket to avoid bloating.

(4) *Mammitis*, inflammation of the udder, is a condition that may affect any nursing female, but more especially the dairy cow. It is generally due to exposure to cold or wet or to injuries to the udder. If the inflammation is only slight it may be relieved by rubbing the udder with camphorated ointment and painting with a weak iodine ointment. The more advanced cases should be treated by giving the subject a laxative, epsom salts, and by bathing the udder, for an hour at a time, with warm water, followed by rubbing dry and rubbing with camphorated ointment or alcohol. Care should also be taken that the subject be given a soft dry bed.

CHAPTER XX

DEVELOPMENT

264. Growth Determination.—Every individual is possessed, at the time of fertilization, of a hereditary factor which circumscribes its future possible development (physically, mentally, or functionally); regulates within certain limits both the rate and period of development; and also acts as a stimulant to the attainment of that development. Livestock men are particularly concerned with the physical and functional development, as these are the two of greatest importance in livestock and the two that can be most accurately measured.

That the individual's possible development is circumscribed at the time of fertilization is perfectly obvious; that a Shetland foal might attain the size of a draft horse or ever be anything but a Shetland pony would be a perfectly preposterous supposition. And in a like manner, each individual is possessed of a growth determiner which stimulates the individual to attain a certain development.

The individual's possible development is dependent upon the rate and period of growth, both of which are also determined within certain limits by a hereditary force. The new-born pig weighs only about one-third as much as the new-born lamb; yet, at the end of six months, the pig will weigh (both having been well fed) about two and one-half times as much as the lamb. This is due to the fact that the pig's growth rate for the first six months is approximately seven times that of the lamb. In a like manner, the period of growth is laid down. Morgan¹ points out that the

¹ Morgan, *Experimental Zoology*.

growth rate in man and rabbit is about the same, but man is much larger at maturity, because the period of development in the rabbit is only a few months while in man it is about two decades.

The above draws attention to the differences in species, which are more marked; yet the same differences exist between individuals. Stockmen are well aware that some individuals grow very rapidly during the first part of the growing period and then stop, while others mature slowly—in the case of cattle and horses, often taking a year or even two years longer to reach full maturity. Stockmen are also aware that this runs in family lines, certain strains developing more rapidly and others more slowly and over an extended period of time.

That there is a vigorous inherent attempt on the part of every individual to attain its maximum development and to attain the same within the usual growing period, even though its attainment be interrupted by a period of partial starvation, was demonstrated at the Missouri Experiment Station.² Two beef calves of similar breeding, one three and the other four months old, were fed starvation and liberal rations, respectively, until they were twelve months old, after which they both were full-fed. At the commencement of the test the three-months-old calf weighed 175 pounds, and the four-months-old calf weighed 200 pounds. When a year old, as the result of different amounts of feed, the former weighed only 212 pounds, while the latter weighed 875 pounds. The calf fed the starvation diet, while undersized and stunted in appearance, had increased in size of bone and length and height of body. As the result of liberal feeding during the second year of their lives, the stunted calf increased its weight of 212 pounds to 1055 pounds, a gain of 843 pounds in one year; and the calf full-fed from birth increased its weight from 875 pounds to 1375, a total gain of only 500 pounds. Not only were more

² Mumford, F. B., *The Breeders' Gazette*, Sept. 29, 1921.

rapid gains made the second year, but 40 per cent less feed was required per pound of gain, by the calf that was underfed during part of its life.

The above-quoted experiment demonstrates that, even though it be necessary to retard growth for a time owing to a scarcity of feed, the individual's inherent forces will attempt to compensate for its former encumbrance by an increased rate of growth. That under certain conditions it may be practical not to full-feed (not a starvation diet as above) commercial cattle was demonstrated by Hunt.³ As the result of wintering two-year-old steers in different degrees of condition preparatory to finishing on grass, it was found that those steers wintered in a thin condition, when first turned to grass will make the most rapid gains; and that heavy steers, heavily fed during the winter, will not make satisfactory gains when turned to grass.

265. Development and Growth.—While it is true that the individual's possible attainments are determined by a hereditary force, the individual's ultimate attainments are dependent upon a complementary force—development. It is also true that under certain conditions it may be economical to retard the development of commercial stock by not full-feeding; yet to develop an individual to its greatest possible capacity, it should be full-fed (full-fed is here used as meaning not all the individual will eat, but all it requires) from the time of fertilization.

266. Intra-uterine Development.—The life of the individual is here considered, as previously (146), as starting at the time of fertilization rather than at birth; hence, the individual's intra-uterine development is as deserving of attention by both stockmen and investigators as its development from birth on. The factors most likely to affect foetal development are (1) its state of nutrition, dependent upon the dam's, and (2) the dam's degree of development.

Records kept for twelve years at the Missouri Station

³ Hunt, R. E., Virginia Bul. 215

indicate that cows when in their prime drop larger calves than when either immature or advanced in age.⁴

That stockmen's observations have led them to believe that the dam's degree of development is a factor affecting the offspring's development was indicated by thirty-six New Mexico ranchers' ⁵ replies to the question: "How much heavier will the yearling steers from heifers bringing their first calf at three years be, than those from heifers bringing their first calf at two years?" Of the thirty-six, only six indicated that there would be no increase, while the average of the increase indicated by the other thirty was 62 pounds. This difference (granting that their observations were correct) might be accounted for in one of three ways, viz., (1) that the older heifers afforded more room during foetal development, (2) that the older heifers afforded their offspring a better state of nutrition while *in utero*, and (3) that the older heifers afforded their offspring a better state of nutrition after birth. That the older heifers would give more milk after parturition; that they, during their offspring's foetal development, would be able to nourish them more properly, since their own body needs would not be so great; and that they would be stronger and better able to rustle feed, is hardly questionable. That the size of the uterus might have something to do with the development of the foetus is a hypothesis offered by the writer as a possible explanation for the differences in the development of calves and colts born of immature and mature parents, as noticed by stockmen, whose younger females would not be under the restricted conditions of feed often necessitated by range conditions, and whose new-born calves would not be restricted in their feed.

In experiments by the Missouri Station ⁶ as to the good or evil effects, upon the offspring, of breeding very young

⁴ Turner, C. W., The Breeders' Gazette, March 22, 1923.

⁵ Lantow, J. L., New Mexico Extension Circular 74.

⁶ Mumford, F. B., The Breeders' Gazette, March 8, 1923.

sows, somewhat contrasted results to those noted above were obtained. For ten generations, very young sows out of litters from very young sows were selected for the experiment, and they were bred at the first occurrence of oestrus. The results over large numbers indicated that it took a slightly longer time for pigs out of immature sows to reach the 250-pound weight than for pigs out of the same sows when mature. This difference was accounted for as being due to the young mother's inability to produce as much milk as the older one. But as regards the early breeding of sows affecting their offsprings' quality, very negative results were obtained; since the three first prize barrows, exhibited by the University of Missouri at the International Live Stock Exposition in 1916, were out of a sow which was of the sixth generation of continuous breeding of immature sows.

While these results are somewhat different from those noted by the New Mexico ranchers, they are not necessarily contradictory; since the sow, being a multiparous animal, generally produces fewer offspring while immature than later; therefore, her offspring would not necessarily be more crowded or restricted in nourishment while *in utero*, and owing to their decrease in number they would not be undernourished after birth in the same degree that a calf from an immature heifer might be. These results do, however, indicate that any restriction in size of the offspring, due to the immaturity of the dam, is not hereditary.

Investigations by Hart, Steenbock and Humphrey⁷ demonstrated very conclusively that the dam's state of nutrition during pregnancy has an influence upon the development of her offspring. It was found that rations balanced from the oat or wheat plant were so low in minerals as to cause pregnant cows to abort or drop dead or very weak calves (Fig. 61). It was also found that the wheat embryo carried a toxic substance which, if present in large amounts

⁷ Hart, Steenbock, and Humphrey, Wis. Bul. 287 and Research Bul. 49.

and fed over an extended period of time, even though the dam received supplementary feeds, would cause the calf to be born weak and blind (Fig. 62). On the other hand, those cows fed rations balanced exclusively from the corn plant produced vigorous, healthy calves (Fig. 63); and those fed the wheat ration with the addition of corn stover dropped

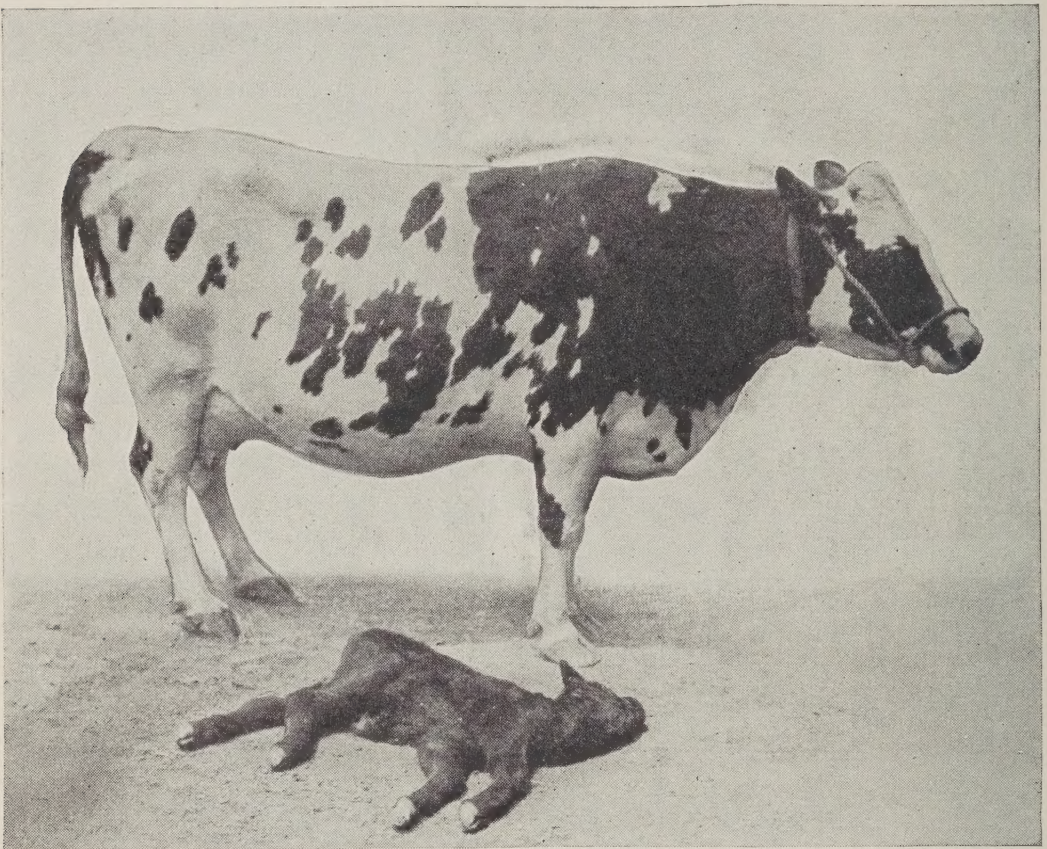


FIG. 61.—Aborted or dead calves, the result of feeding cows a balanced ration from the oat plant. The ration was too low in minerals. (*Courtesy University of Wisconsin.*)

healthy calves (Fig. 64). The corn stover apparently counteracted the poisons from the wheat middlings.

Very similar results in regard to the feeding of an exclusive oat ration to pregnant ewes were obtained by Dowell.⁸ Pregnant ewes fed on a "green oat-feed ration" (a very popular feed in the Northwest) and upon an "oat-straw

⁸ Dowell, *Farm and Ranch Review*, Oct. 5, 1920.

and oat-grain ration " produced a large percentage of weak lambs; while those fed alfalfa produced strong, robust lambs.

Evvard ⁹ has also shown that a ration poor in protein and minerals will cause pregnant sows to drop undersized and weak pigs. Corn grain is deficient in both protein and



FIG. 62.—Calf born blind and weak, the result of feeding the dam continuously on wheat supplemented with alfalfa. The wheat embryo carries a toxic substance. (*Courtesy University of Wisconsin.*)

calcium, and those pregnant sows fed exclusively upon corn dropped pigs whose average weight was only 1.74 pounds and the percent of strong pigs was only 68; while those sows fed on a "corn plus meat meal ration" dropped pigs whose average weight was 2.23 pounds and the per cent of strong pigs was 93.

⁹ Evvard, Iowa Academy of Science, report, 1913.

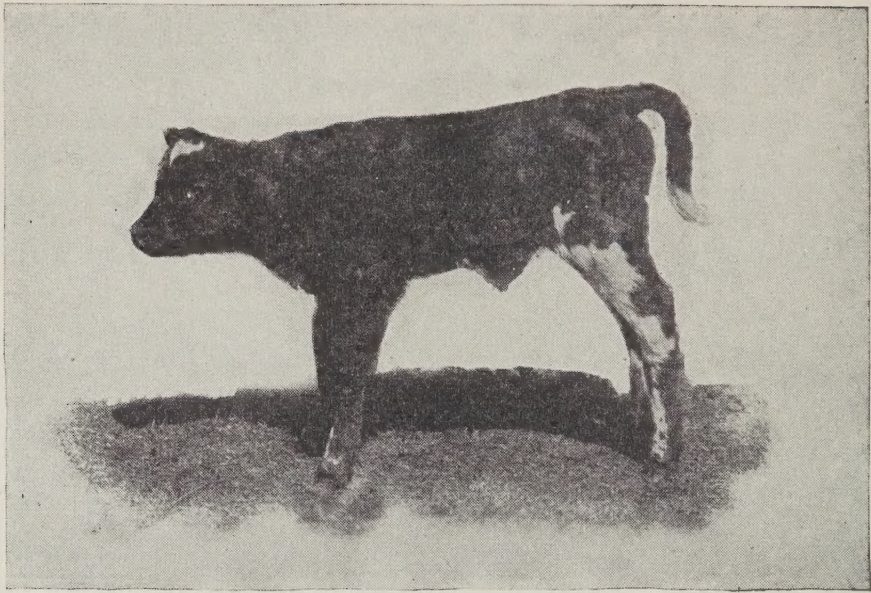


FIG. 63.—Strong healthy calf, the result of feeding the dam a corn ration.
(*Courtesy University of Wisconsin.*)

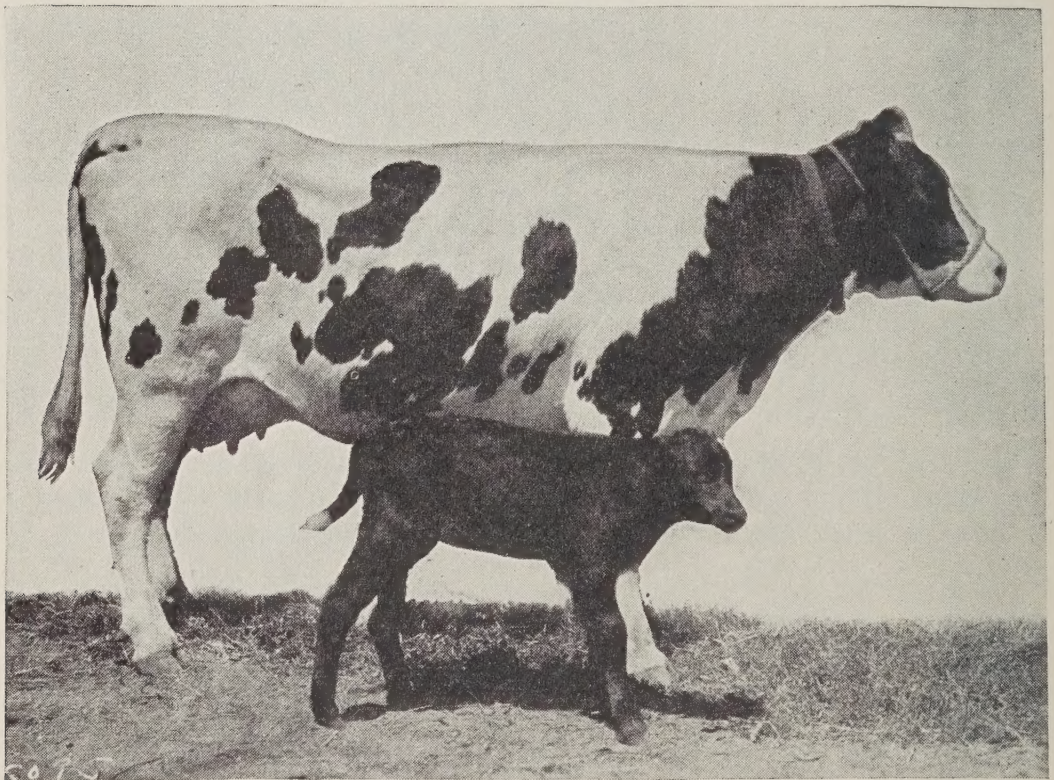


FIG. 64.—Normal calf, the result of adding corn stover to the dam's wheat ration. (*Courtesy University of Wisconsin.*)

It has also been shown that rations deficient in iodine, fed pregnant females, may be the cause of hairless pigs and goiters in lambs.

The above-quoted results all indicate the great need for stockmen to pay strict attention to the feeding of their pregnant females in regard to amount, balance of rations, balance of the protein itself, an adequate supply of minerals, and the source of the feeds themselves.

267. Development from Birth.—While, as already indicated, every individual is possessed of an almost ineffaceable imbued force that strives to attain for the individual—even though its normal development has been interrupted by a period of partial starvation—its maximum development as determined by heredity; yet it is questionable whether such an individual ever attains its maximum development. That maximum development is not attained in such cases is indicated by the results of McCandlish, Gillette, and Kildee,¹⁰ regarding the milk production of three groups of related scrub cows brought to the station as mature cows, as four-year-olds, and as calves, respectively. All had been underfed previous to their arrival at the station, after which they were well fed; and they received similar treatment during their lactation periods; thus any differences in their productions must be attributed to differences in feed and care during the early part of their lives (Table XXXVIII). It will be noted that those cows arriving at the station as four-year-olds, thus able to complete their growing period under favorable conditions, produced 14 per cent more milk and 8 per cent more fat than their scrub relatives who had spent their whole growing period under unfavorable conditions; while those arriving at the station as calves, thus reared for nearly their full lives under favorable conditions, produced 27 per cent more milk and 24 per cent more fat than those not receiving favorable treatment until mature.

That the Dutchland Farms (famed for their production

¹⁰ McCandlish, Gillette and Kildee, Iowa Bul. 188.

of 1000-pound cows) consider not only liberal feeding but the kind of feeds an important factor in determining the heifer's future production, is expressed in the following:¹¹

“ We wish to place special emphasis on the importance of giving the calf, after it is a few months old, a liberal amount of hay. No one thing is so helpful in developing a large barrel and increasing the animal's capacity as a generous amount of hay during the early stages of its life.

TABLE XXXVIII
AVERAGE PRODUCTION OF SCRUB COWS *

Group	Number of	Number of Lactations	Average Production		Increase Production	
			Milk, Pounds	Fat, Pounds	Milk, Per Cent	Fat, Per Cent
Mature.....	5	15	3168.7	153.64		
Four-year-olds .	2	15	3557.7	166.36	14	8
Heifers.....	7	28	4036.1	191.21	27	24

* Iowa Bul. 188.

“ We have all seen heifers that were fed mostly on silage that were deficient in barrel, and we who have been through this experience know that such heifers will never make the records that they would have made had they had less silage and more hay through the developing stage.”

That the individual, following a period of restricted feeding, will make a most vigorous attempt, due to inherent forces, to regain its normal growth was demonstrated at the Missouri Experiment Station (264); it was also demonstrated by that Station that such an individual would not fully recover what it had lost.¹² One steer was full-fed from birth, and another was given a maintenance ration (sufficient feed to allow it to maintain a uniform body weight) from three months old to thirteen months; at

¹¹ Dutchland Farms, The Breeders' Gazette, Dec. 28, 1922.

¹² Mumford, F. B., The Breeding of Animals, p. 268.

fourteen months of age the full-fed calf weighed 956 pounds; at thirteen months the underfed one weighed only 207 pounds. While the latter made more rapid gains from this time on—both then being on full feed—he never attained the weight of the other; at thirty-eight months of age he weighed 300 pounds less and was shorter and finer of bone.

The above-quoted results of careful observations and experimental work tend to emphasize the fact that stockmen, if they would get the best out of each individual, must pay strict and regular attention to the feed and care of their young stock.

268. Effect of Early Pregnancy.—In reply to the question:¹³ “Have you bred heifers to calve at two years for several generations?” eighteen New Mexico ranchers replied that they had not, while thirty-one replied that they had. In the same inquiry, in answer to the question: “Do you note any marked decrease in the size of your mature cows following this practice?” five said they could see no ill effect, and thirty-five said they had noticed a decrease in size, one of whom estimated it at 20 per cent.

These observations are in keeping with those of many other stockmen, i.e., that it is not well for the individual to be bred too early in life. Therefore, for general practice, subject to variations due to differences in development, the following dates of first breeding for farm animals are recommended:

Species	Age
Sow.....	6- 8 months
Ewe.....	1½ years
Heifer:	
Beef.....	20-26 months
Dairy—	
Jersey and Guernsey.....	15-19 months
Holstein-Friesian and Ayrshire..	21-25 months
Mare.....	3 years

¹³ Lantow, J. L., New Mexico Extension Circular 74.

269. Development Later in Life.—Just what percentage of our livestock remain unappreciated even after maturity, because of a lack of proper feed and care, is unknown, but the number is undoubtedly high. A very striking illustration of this is to be found in the record of the Holstein-Friesian cow, Bella Pontiac: she was purchased by Tom Barren at a farm auction sale, for \$170, and in his hands she broke the world's butterfat record for one year, two years, and three years.



FIG. 65.—Condition adds sale value to animals. This team netted the consignee \$190 at Chicago; a year later, in condition, \$1500 was refused for the team. (*Courtesy The Breeders' Gazette.*)

A somewhat similar illustration is furnished by a pair of Clydesdale stallions, three and four year old, purchased at the Union Stockyards of Chicago by Wilson & Co., for \$400.¹⁴ After the expenses of selling were deducted, they netted the consignee \$190. At the time of purchase they were very thin. Wilson & Co. put them on a liberal ration, castrated them, and upon their recovery put them to work. At the time of purchase they weighed only 2614 pounds;

¹⁴ Ashton, John, *The Breeders' Gazette*, March 24, 1921.

one year later they weighed 3600 pounds (Fig. 65), at which time \$1500 was refused for the pair. The intention was to put the pair in the famous Wilson six-horse team, but this was rendered impossible by the death of one of the horses.

Both the above illustrations furnish striking examples of outstanding animals "going begging" for a little extra feed. Only real stockmen are able to appreciate an animal's merit when in the rough, but almost everyone appreciates it when the same animal is finished; therefore, to show animals to the best advantage when offered for sale, they should be put in condition.

CHAPTER XXI

DEVELOPING A BREEDING ESTABLISHMENT

270. Livestock Breeding, a Business.—Livestock breeding is a business; and like all other lines of business, it affords plenty of illustrations of those who have achieved success and of others who have failed. Livestock breeding, however, differs in one outstanding characteristic from other business enterprises, in that in recent years it has attracted many men of means, to whose passing fancy it may for a time serve as a source of diversion and recreation. No enterprise of a business nature, however, can long hold a businessman's interest, approbation, or regard that does not lend itself to being placed upon a business footing. A man's success or failure in the livestock breeding business, as in most other lines of business, depends very largely upon the following three factors: (1) his ability to produce a superior product, (2) his ability to produce that product economically, and (3) his ability to sell that product for its true value.

It may sometimes seem that modern business is not founded upon the above three principles; but a close examination of the various manufacturing concerns will reveal that those which endure—and a business cannot be called successful unless it does endure—almost invariably produce the best product of that particular kind and thus win the public's respect and esteem. Furthermore, it is essential that the product be produced economically, to enable the producer to meet competitive prices and yet retain a profit; and selling a product for its true value is

essential to success, since selling for less is obviously poor business, and the business that sells for more will not long hold public approval.

271. Selecting the Farm.—In the selection of a farm for the breeding of livestock, there are two main points of consideration: its proximity to markets and its adaptability to the raising of the particular kind of stock the breeder would raise.

An important point in the selection of a farm is its location with regard to prospective “farmer buyers.” A neighborhood that has been using purebred Shorthorn bulls for a long time is not very likely to absorb many Hereford bulls, or *vice versa*. Every breeder, no matter how constructive, will have some males which are not fit to head a purebred herd, flock, or stud, but are yet good enough to do creditable work on grade females.

Many new breeders are hesitant about locating near other prominent breeders having the same breed. The modern method in business, however, is not to keep clear of competition but to find the center of the trade and get established in that center. A community that has several breeders raising a certain breed will attract outside buyers, because buyers would rather go to a district, where they can visit several herds, flocks, or studs than visit only one. Thus the new breeder reaps the reward of much of the advertising of these older breeders. The fear that the older breeders will eject him is unjustified; because the vast majority of the successful livestock breeders are big, broad-minded men who not only realize that a new breeder in their midst is an asset—for he, if successful, will add to the neighborhood’s reputation and will also be in the market for some of their stock—but in addition they have the breed’s welfare at heart and take a kindly interest in the new breeder’s success.

A farm located close to a town and a main railroad line is a decided advantage. Buyers, like everyone else, con-

sider comfort, convenience, time, and expense. Many buyers will not visit the farm located on a branch railroad line where the service is poor, or the one located far from the railroad station, because of the time and expense involved in getting to a farm of this kind. Once well established, most breeders hope to hold auction sales, in which case being close to town is a decided advantage, for the breeder is expected to arrange the visitors' transportation to and from town. Being near a fair-sized town is an advantage because of the added hotel convenience for prospective buyers at either private or auction sales.

Being located next a main railroad line or a main highway is also an asset, for many people will see the stock in passing, and if they are of good quality it will help to spread the breeder's reputation.

The adaptability of the farm itself to the particular class of stock that the breeder would raise should be carefully considered. A farm that would successfully raise cattle, sheep, or horses must afford ample land, suitable to the raising of roughages—especially a legume hay—and pasture. A soil that is rich in lime is an important consideration, for the stock raised on such a farm will receive more lime and consequently develop more bone. The quantity and quality of water available should also be carefully considered, since pasture land with shade and running water furnishes a most favorable environment for the development of stock (Fig. 66).

In selecting a farm for breeding purposes it is also well to ascertain whether the farm has ever—more especially during recent years—experienced any outbreaks of infectious diseases.

272. Selecting the Class and Breed of Stock.—In the majority of cases the new breeder is not confronted with the problem of selecting a farm, for he already has one; his first problem, therefore, is the selection of the class and breed of stock best suited to his particular conditions.

The new breeder's choice of a class of stock will be determined very largely by his personal tastes and past experience, although even here he must use discretion, for certain districts do not afford a market for certain classes of stock. It would be folly to start breeding dairy cattle in a ranching district, or to breed beef cattle in a large dairy center. Since it is rather difficult to convert a dairyman into a beefman or a sheepman into a horseman, etc., the man who is hopelessly addicted to a certain class of stock



FIG. 66.—Abundant pasture with shade and running water furnish a favorable environment for the development of livestock.

would do better to sell his farm, if not suitably located for the rearing of his chosen class of stock, and locate in a more favorable district. Many districts, however, offer suitable market facilities for all classes of stock.

The man who has a strong liking for, and who has had considerable experience with, a certain class of stock will do well to continue with that class. The choice of breed within the class, as previously discussed (271), had best be determined by the prevalence of both grade and purebred individuals of that breed in the neighborhood, for most

men can learn to like another breed of the same class as well as they did their first choice, and the method of handling would be practically the same.

273. Experience with Grades.—As in other lines of business, experience is necessary for success; therefore, the new breeder with limited livestock experience had best gain his experience from grades rather than purebreds. Many a man has gone into bankruptcy in the purebred business, simply because he had not had the necessary fundamental experience, in caring for and feeding livestock, to handle purebreds.

274. Selection.—A thorough understanding of the problem of selection and its sub-problems is fundamental to success. Selection is discussed in detail in Chapter XV.

275. Breed-in, not Buy-in.—Breeding-in is a safer practice than buying-in. It is only the man with considerable means who can afford to invest the necessary capital to procure a full herd, flock, or stud of select animals. The beginner, with limited resources, will do well to buy only one or two of the best safely bred females obtainable, letting them serve as his foundation stock. With a fair degree of success, and by keeping all their female offspring, he can build his whole herd, flock, or stud around the one or two choice females. Besides these choice females, it will generally pay him to buy several good useful individuals of the plainer sort, for he will need several females in order to afford the use of a good sire; furthermore, the plainer ones will do as well at the start, because they are not so expensive and he cannot hope to sell his stock at top prices until he has gained a reputation.

276. Selection of the Sires.—Every breeding establishment should have at its head a sire of the best individuality and breeding that it can secure (209). While the term grading is not used in connection with purebreds, yet the principle put into practice should be the same: the breeder should aim to have each new generation better than the

past. This is possible only where the sires used are better and stronger than the females.

A good illustration of the improvement that may be accomplished by the use of exceptional herd sires in the purebred herd is furnished by the Mixter Farm, breeders of Guernsey cattle.¹ The foundation females were plain individuals, one of them costing only \$100; yet, by the use of good sires many high-priced animals have been sold from the herd, one selling for \$5000. Many good records have been made at the farm and by individuals or descendants of individuals sold from the farm, one of which for a time held the world's double Roll of Honor record.

277. Culling.—Weeds grow in every garden, and the wise gardener pulls them out. In a like manner, the wise breeder uses his knife on the inferior males, and puts the inferior females in the feed lot. Many breeders ruin their reputations by keeping inferior males in the hope of selling them at farmers' prices. Many purebred sires are unfit to be used even on scrub females; but neither the breed's nor the breeder's reputation would be marred if these animals were not palmed off on innocent buyers. Furthermore, the sale of a good steer, barrow, wether, or gelding will generally net the breeder more than that of a poor breeding male.

278. Development.—The importance of development, for the good of the individual animal and for that of the race, was previously discussed (Chapter XX). In a like manner, it is essential to financial success that the breeder fully appreciate the importance of keeping his animals in a thrifty condition, and it is especially important that those offered for sale be kept in fit condition. Almost everyone has seen animals of good breeding and of really good individuality offered for sale in a most disreputable condition.

279. Records.—Records are indispensable to the successful conduct of any business enterprise. The livestock breeder should have a system of keeping records that is

¹ Miller, Walter L., *The Breeders' Gazette*, Aug. 17, 1922.

not too complicated but yet gives a record of the necessary facts concerning each animal. The system used will depend to a very large extent upon the class of stock and upon the breeder's personal tastes regarding methods of keeping records. A few of the absolutely essential records regarding each animal are the following: date of birth; marking, natural or artificial; ancestry; anything unusual regarding the animal's development; in the case of animals that have been sold, price and to whom sold; in addition, in the case of females, their date of breeding and sire bred to; offspring produced; and if dairy cows, their production records.

The record regarding animals sold is one too commonly omitted. It is a very good thing to have a record of all sales, and occasionally to find out if the animals sold turned out as they should. It shows the buyer that the breeder wishes to give satisfaction, with the result that the buyer is far more likely to return for more animals.

Frequently, breeding records are not kept accurately, with the result that the wrong information is often given buyers regarding purchased animals. The buyer thus gains the impression that the seller is dishonest, and hence thereafter he goes elsewhere for his purchases.

280. Economy.—In livestock breeding, as in all other lines of business, economy is necessary to success. It is not enough to produce good individuals; but since most men are in the business for a profit, these individuals must be produced at a reasonable cost.

For the average man, the use of home-grown feeds is by far the best policy; it is a policy which involves less risk and it is generally cheaper. The real reasons for raising livestock, which are to furnish a suitable market for the farm crops and to retain the soil fertility, should always be kept in mind. The real reason for the existence of pure-breds is that they will furnish a better market for these crops than scrubs or grades. Some breeders buy most of

their feed, but it is a questionable practice. Certainly most, if not all, of the roughage should be raised on the farm; and if most of the concentrates are home-grown, the breeder is not undertaking the obligations he is if they are purchased. It is, however, almost always necessary to purchase some special feeds, as oilmeal, bran, etc.

Furthermore, the business itself, to be successful, must be conducted, all the way through, on a strictly business basis.

281. Advertising.—Advertising is absolutely essential to any modern business that is dependent upon selling to the public. The new breeder need not worry about advertising, however, until he has something to sell. If his surplus stock is mediocre he will do much better to advertise only in his local papers, for buyers do not travel far to purchase that class of stock. By the time he has considerable stock or something especially good to sell, he will be ready to advertise in the agricultural press of his district, his breed paper, or even the national agricultural periodicals. Many breeders, once they are well established, find that it pays to run a small advertisement continually in one or all of the above-mentioned classes of papers and then run large advertisements previous to large offerings.

One of the best forms of advertising is the exhibiting of stock at the leading livestock shows. As soon as the breeder has something good, he can well afford to show his stock at fairs of a size proportionate to the quality of his stock.

282. Selling.—Successful sales are the necessary conclusion to any successful productive enterprise. Many men are good breeders of livestock but poor salesmen, and in such cases a partnership often proves of value. Amos Cruickshank was a great breeder, but not a decided success either as a salesman or a businessman. In that particular case, partnership with his brother, Anthony, who was a real businessman, proved invaluable not only to financial success but to successful breeding, because satisfactory returns are

necessary in order that a business may go ahead. Salesmanship is a vocation in itself, and one that is very essential.

283. Public Sales.—The public sale is one of the best means of disposing of surplus stock for those having large numbers. The sale should be advertised as widely as the merit of the stock warrants. If the stock is plain, there is no use advertising at great distances; but all sales, big or small, should be advertised at home, as it is desirable to cultivate the home market, which will then absorb most of the plainer individuals that buyers from a distance seldom buy.

Catalogs must be issued, and many breeders are finding it cheaper to list the entire offering in the breed paper, thus letting that serve as both the advertisement and the sale catalog. Neat, attractive catalogs aid in drawing buyers, but the amount spent on them can easily be overdone.

Holding the sale in a main railroad center or in a good railroad town aids in bringing many buyers, but it is an added expense that must be carefully considered before undertaking. If the sale is held on the farm, a suitable sale ring is necessary, and the conveyance of outside visitors, to and from the farm, must be provided.

In order that the sale may be successful, an experienced auctioneer is necessary; but it is generally discreet to use the home auctioneer as well, for he can keep the home folks in good humor and often pick up many bids through his intimate knowledge of their various individualities.

The manner in which the animals themselves are presented has a great deal to do with the success of a sale. It is not necessary that they be in show condition, but they should be well conditioned. They, if cattle or horses, should be well halter-broken; and a dressing previous to their entering the show ring adds greatly to their appearance.

CHAPTER XXII

COMMUNITY BREEDING

284. Development of Community Breeding.—In Europe, the community breeding of farm animals is the rule, while in America it is rather the exception. That this should be the case is but natural: in Europe the farmers of a certain district are of one race; their chosen breed has been developed by their neighborhood or at least not far away; the on-coming generations have accepted the breed as their heritage; and as they do not travel far, a variety of tastes is not developed. In America, the reverse is true: our people have been drawn from many lands, consequently they have brought varied tastes regarding breeds; while we have developed some very important breeds of livestock, European breeds have played the larger rôle; and with the development of the country our people have moved about a great deal, with the result that it has been the exception rather than the rule for son to succeed father, and furthermore most communities are always shifting—each new-comer bringing his own chosen breed.

In Europe, community breeding was, for the most part, but a natural outgrowth; in America, while we might point to many districts where community breeding has developed naturally—Merino breeding in Vermont, Ohio, and Pennsylvania, and the breeding of American Saddle Horses in Kentucky and Missouri—yet it, in the main, has been brought about through organized effort. The first organized effort toward community breeding, however, took place in the Island of Jersey when, in 1763, the importation of other

than Jersey cattle to the island, excepting for slaughter, was prohibited by law.

In America, the Western Reserve Holstein-Friesian Association, organized in 1905 at Burton, Ohio, was, so far as the writer could ascertain, the first organized effort toward community breeding. The association has been most successful, cattle having been sold to various parts of America as well as to South Africa, Mexico, and Japan.

From a membership of 10, the Wakesha County (Wisconsin) Guernsey Breeders' Association, established in 1906, has grown to be one of America's most notable examples of community breeding.¹ In seven years, Guernsey cattle increased 700 per cent in the county; from 1910 to 1914, the county's average butterfat production per cow increased 100 pounds; and at the association's annual sale in 1918, cattle to the value of \$23,460 were sold in one day.

Another community of international repute, because of its success achieved through the cooperative breeding of Holstein-Friesians, is the New Salem (North Dakota) Breeding Circuit. The first purebred dairy cattle were purchased in 1906, no one taking more than two head; and the circuit was first organized in 1909. It then consisted of 12 members, and has since grown to 17, 10 of whom are of the original 12.² A superintendent is employed to test each member's cows regularly and help the owners keep feed-cost records. The members advertise their cattle cooperatively, and whenever a purebred animal is sold, 5 per cent of the sale price is retained by the circuit for promotion purposes.

The following figures illustrate the results accomplished: the average butterfat production of one herd of 17 cows, the first year, was 131.9 and the average net profit was \$16.90; seven years later the same herd, now composed of 14 cows, made an average butterfat production of 426.6

¹ Plumb, C. S., *American Sheep Breeder*, Dec., 1919.

² Sheperd, J. H., *North Dakota Circular* 45.

pounds and an average net profit of \$90.24; and in 1920, a very short crop year, the 17 circuit members averaged more than \$2300 of gross income per man from milk products and surplus stock.

The Delaware County (Ohio) Percheron Breeders' Association, organized in 1913, affords a very good illustration of a successful community horse-breeding organization. In 1919, the association had 85 members, and each fall the association holds a very successful Percheron show.

The above are but a few of the more outstanding examples of successful community breeding of livestock; many more might be mentioned. A great many organizations have been formed since about 1918.

285. Advantages.—One breed, whether grades or purebreds, is better for a community than many. Buyers prefer to go where the range of selection is wide, and this is what community breeding offers them. Such a district gains a reputation for its stock and thus more buyers are attracted. This is especially true in the case of purebreds, but it is likewise true in the case of grade horses and dairy cattle. In the case of block animals, one breed in a community enables the farmers to ship a more uniform product, which always sells better than mixed lots.

Community breeding renders possible the exchange of sires; thus the expense of sire replacement is reduced to a minimum, and the community is enabled to retain the exceptional sire throughout his full period of usefulness. To the small breeder, who must exchange sires about every two years, and who wishes to use really good sires, the expense of replacement is necessarily heavy unless the old sire can be salvaged at more than block prices. The exceptionally good sire should be used throughout his whole life; the small breeder cannot do this, but by community breeding this sire may be retained in the neighborhood. In the case of dairy cattle, many an exceptional sire has been sent to the block before he was appreciated. Several factors

have been responsible for this; but the outstanding one has been that the small breeder was in need of a new bull to use on his present bull's daughters, the size of his herd did not justify the keeping of two bulls, and the present bull's daughters, being too young to be tested, were, like their sire, unappreciated.

The small breeder is at a great disadvantage in the sale of stock; he cannot put on a widely advertised sale, for his amount of stock neither justifies elaborate advertising nor attracts many outside buyers. Most national, state, and provincial breed organizations have annual or semi-annual sales; but they cannot handle all a small breeder's surplus stock, and as a rule only the most select are wanted—which is as it should be—for these consignment sales. By community breeding, local consignment sales and joint advertising of the same are possible and this insures the consignee a maximum of service at a minimum of expense. In addition, stock offered for sale throughout the year is often advertised jointly; thus again attracting a maximum amount of attention at a minimum amount of expense.

Still another big advantage is that, by having one common purpose, the promotion of their chosen breed, the breeders find that they have many things in common, with the result that cooperation all along the line often follows. The New Salem Breeding Circuit has led the way to the cooperative purchase at wholesale prices of both silos and milking machines, joint ownership of bulls, circuit thrashing and silo filling, and finally the working toward a common purpose, the improvement of their community and everyone and everything in it.

All the above leads to an exchange of ideas; linebreeding, inbreeding, pedigrees, and the current history of the breed are studied and discussed, with the result that everyone is benefited. This naturally leads to the discussion of other topics, and hence to a broadening of the educational horizon of everyone.

286. Difficulties.—The obstacles in the way of community breeding are not, as a rule, big wholesome ones, but little petty affairs, such as jealousy, spite, and old grudges, which are often extremely difficult to remove. On the other hand, the man who has spent considerable time and money upon a certain breed is perfectly justified in hesitating about changing to another breed. When such is the case, the better solution is to reduce the number of breeds as far as possible, the breeders of each breed organizing separately and all forming a larger organization, the purpose of which is to promote the interests of all.

287. Organization.—A cooperative organization's articles of incorporation are not so important as the spirit and intent behind that organization; but, nevertheless, the simpler the method of organization the greater chance the cooperative enterprise has of being a success. Some cooperative breeding clubs are so organized that the club as a whole indorses the individual in his purchase of breeding stock, this being necessitated by some members' shortage of capital. This is a very doubtful practice, for the individual whose financial standing is such that he cannot stimulate enough confidence to be enabled to borrow the necessary cash himself is extremely unlikely to prove an asset to the club; neither are the purebreds likely to prove an asset to him. It should be distinctly and thoroughly understood by farmers that the mere keeping of purebreds does not offer a catholicon for all their ills; and furthermore, there are many who have not the capacity to handle purebreds creditably. Therefore, the organization had best only provide for such things as joint ownership of sires and cooperative purchases, advertising, and sales, thus letting each individual finance his own herd as his means permit.

288. Bull Associations.—Community breeding makes bull associations possible and, in a like manner, bull associations lead to community breeding. Cooperative bull associations were first suggested by Professor R. S. Shaw, in

1907, to the Michigan State Board of Agriculture, with the result that by the efforts of the Michigan College of Agriculture three cooperative bull clubs were organized in that state during 1908. Bull associations have since spread to other states, and at the end of 1921 there were 158 such organizations in the United States.

289. Advantages.—Since the bull association paves the way for community breeding, it includes all the advantages of community breeding and several others as well. The purpose of the organization being to reduce the number of bulls, it enables the members to have the use of better bulls at a lower cost per farm. Such was the experience of the Roland Cooperative Bull Association in Iowa:³ the association was composed of 16 farmers, and was divided into 5 blocks; at the time of organization each farmer had an average investment of \$89 in a scrub bull; these bulls were disposed of and 5 purebred bulls purchased at an average cost of \$240 each or an average cost of \$75 for each member; thereafter, each member had the use of a good purebred bull, with \$14 less invested in him; furthermore, only one bull had to be fed where 3 or 4 were previously fed.

Linebreeding, which is conducive to uniformity and rapidity of results, is rendered possible by the bull association. All the bulls being purchased at one time, this fact could and should be kept in mind.

One of the greatest advantages of all is that the bull association places a good purebred bull within the reach of every farmer, regardless of how small his herd may be.

290. Organization.—The typical cooperative bull association, as organized, is composed of from 15 to 40 farmers, the average number for 1918, 1919 and 1920 in the United States being 38, who jointly own 5 bulls.⁴ The association's territory is divided into 5 blocks, one bull being assigned each block. The average number of cows, for the same

³ Winkjer, Joel G., *Farmers' Bul.* 993.

⁴ Pirtle, T. R., *A Handbook of Dairy Statistics*, U. S. Dept. Agr.

period, per block was 48, and the average number per association, 233. The bull in each block should be kept on the farm most conveniently situated to all other members. Each bull is allowed to stay in one block for two years, at the end of which time bull No. 1 goes to block No. 2, bull No. 2 going to block No. 3, and so on. In this way, if all the bulls live and if all are retained, no second outlay for bulls need be made for ten years.

Before joining, each farmer should be made to understand thoroughly that the breed selected at the time of organization is not subject to change. Therefore, the breed question must be gone into completely at that time. The most satisfactory way to settle that question is to get a competent, open-minded speaker, preferably from the state or provincial Agricultural College, to thoroughly discuss the breeds in question; and then to settle the matter by ballot, all first agreeing to accept the breed thus chosen by the majority.

291. Constitution and By-Laws.⁵—A cooperative bull association should be incorporated under the state or provincial law governing such cooperative organizations. In this way the liability of the individual members for the debts of the entire organization are limited.

292. Similar Organizations.—Bull associations have attracted more public attention than similar organizations in other classes of stock; but stallion clubs have been fully as influential in the development of horse breeding in certain districts. A stallion club may provide for the joint purchase of one or a ring of stallions, or for the clubbing of a good stallion from some leading breeder. The latter practice, which is very common in Scotland and Western Canada, is to be preferred to the former whenever possible, because there is a greater likelihood of the stallion being properly cared for.

⁵ Winkjer, Joel G., *Farmers' Bul.* 993, presents a copy of a very good constitution and by-laws.

So far as the writer has been able to ascertain, no boar or ram associations have been formed; but there is no reason why they would not be equally beneficial, and they would enable the thousands of farmers now using nondescript rams and boars to use good purebreds.

293. Cow Testing Associations.—Another very laudable cooperative enterprise is community cow testing. The first cow testing association in the United States was formed in 1906; and by 1921 the number of associations had grown to 452.⁶ These organizations, composed of about 25 dairy farmers, provide for the cooperative testing of each farmer's cows. The association employs a tester whose duty it is to visit each farmer monthly, weighing and testing his milk and aiding him in his feeding and breeding problems. A cow testing association is possible in a community keeping various breeds, and it often paves the way for both bull associations and community breeding.

294. Possibilities.—Community breeding is still in its infancy in America; but each year more communities come to realize the great value to one and all that is to be gained through community effort. Each year teaches the American farmer the utter folly of shifting from district to district and from breed to breed; and as time goes on and American farm practice becomes more stabilized, community breeding is likely to become the rule rather than the exception.

⁶ Pirtle, T. R., A Handbook of Dairy Statistics, U. S. Dept. Agr.

INDEX

A

- Abortion, 254
 causes of, 254
 defined, 254
 improper rations and, 254, 275
 infectious, 255
 channels of infection, 259
 diagnosis of, 258
 dissemination of, 258
 in horses, hogs, and sheep, 263
 loss by, 256
 prevention of, 260
 susceptibility to, 256
 symptoms of, 256
 treatment for, 260
 injuries and, 255
Accidental matings, 162
Achromatin, 17
Acquired characters, 150, 159
 defined, 150
 inheritance of, 89, 151
 belief in, 152
 conditions necessary to prove, 154
 disbelief in, 153
 disproof of, 158
Advertising, 291
Afterbirth retained, 262, 269
Albinoism in cattle, 102, 145
 in horses, 109
Allantois, 60
Allelomorph, 94
American Saddle Horse, 115, 177, 293
Amnion, 60
Amniotic fluid, 60
Amphimixis, 148
Anaphase, 19
Ancestral Heredity, Law of, 120
Anderson, 43, 44, 105, 248, 249, 250
Animal breeding, an art, 3, 167
 a science, 3, 167
 defined, 2
 divisions of, 3
 field of, 7
 foundation of, 7, 13
 problem of, 10
 situation in, 7
 improvement, 1
 rights, 170
Animals, domestication of, 7, 168, 241
Anoestrus, 40
Anxiety 4th, influence of, 129, 130
 linebreeding to, 129, 187
Arabian horse breeding, 175, 252
Atavism, 144
Autosome, 54
Avondale, influence of, 129
- ### B
- Babcock and Clausen, 114, 145
Bacillus abortus, 256
Bakewell, 8, 175
Bates, 185, 192, 197
Blazek sisters, 75
Blending inheritance, 92, 116
 animal breeding and, 120
 Galton's Law of Ancestral Heredity
 and, 120
 studies of, 116, 118
 need for studies of, 123
 rabbits and, 117
 sheep and, 123

Breeder, defined, 167
 Breeding, age of first, 239, 281
 best to the best, 195
 business of, 284, 292
 selection and, 215, 220, 285 (see
 Selection)
 selling and, 292, 296
 community, 293
 cycle, 39
 dioestrus cycle, 39
 early, 171
 by Arabians, 175
 by Bakewell, 175
 by British, 175
 by Egyptians, 171
 by French, 175
 other pavers of the way, 176
 formation of the breeds, 177
 methods, 177
 practice of, 166
 season, 38
 terminology, 178
 test and selection, 220
 time of, 44
 Brilliant 3rd, influence of, 131, 132
 Bull associations, 297
 advantages of, 298
 constitution and by-laws, 299
 organization of, 298
 Roland Cooperative Bull Associa-
 tion, 298
 similar organizations, 300
 Bulldog and variations, 155
 Bunge, 69

C

Calypso, influence of, 132
 Carlson, 251
 Castle, 98, 113, 117
 Castle and Phillips, 158
 Castration, effect of, 56
 Cattalo, 202
 Cell, the, 13
 multiplication, 18
 structure, 14
 theory, 13
 Centrosome, 14, 17

Character, defined, 93
 Chorion, 60
 Chorions in twin births, 48
 Chromatin, 17
 Chromosomes, 18, 89
 accessory, 54
 autosome, 54
 number in the ass, 200
 horse, 54, 200
 mule, 200
 pig, 55
 reduction of, 26, 33
 theory of heredity, 89
 Clitoris, 30
 Closebreeding, 124, 179
 disadvantages of, 180
 experimental, 190
 in-and-inbreeding, 184
 inbreeding, 183
 fertility and, 180, 190, 192, 243
 kinds of, 181
 linebreeding, 181, 298
 practice of, 185
 by Bates, 185, 192, 197
 by Colling brothers, 185, 192, 197
 by Cruickshank, 185
 by Gudgeon and Simpson, 187
 by Lovejoy, 189
 by McKerrow farms, 189
 in Aberdeen-Angus, 188
 in Clydesdales, 189
 in dairy cattle, 188
 in Herefords, 187
 in hogs, 189
 in sheep, 189
 in Shorthorns, 186
 in Shropshires, 189
 in wild animals, 189
 reasons for, 179
 when to practice, 191
 Coffey, 236
 Colling brothers, 185, 192, 197
 Color inheritance in cattle, 101
 in hogs, 110
 in horses, 105
 Colostrum, 69, 267
 Community breeding, 293

- Community breeding, advantages of, 295
 bull associations, 297
 cow testing associations, 300
 Delaware Co. Percheron Breeders' Association, 295
 development of, 293
 difficulties of, 297
 New Salem Breeding Circuit, 294, 296
 organization, 297
 possibilities of, 300
 stallion clubs, 299
 Wakesha Co. Guernsey Breeders' Association, 294
 Western Reserve Holstein-Friesian Association, 294
Conception, 59, 68
 after pregnant, 45
Conformation and fertility, 243
Congenital characters, 150
Constipation, 267
Continuity of the germ plasm, theory of, 87, 153
Cook, 228
Copulation, imperfect, 248
Corpus albicans, 35
 luteum, 35, 65, 76
 retained, 257
Correlated characters, 217
Cowper's Glands, 27
Cow testing associations, 300
Crossbreeding, 194
 bison and cattle, 202
 Braham and European cattle, 203
 breeds, 196
 effects of, 195
 fertility and, 195, 243
 horse and ass, 198, 201
 and zebra, 203
 new breeds by, 197
 object of, 195
 objection to, 197
 outcrossing, 195
 renovation by, 197
 retention of crossbreds, 196
 species, 198
Crossbreeding, variation and, 139, 195
 wolf and dog, 203
Cruickshank, 177, 185, 195, 291
Cryptorchids, 249
Culling chickens, 220
 herds, 289
Cytoplasm, 14, 61
- D
- Darwin, 63, 86, 156, 159
Davenport, 15, 133, 189
De Kol Plus Segis Dixie, 141
Development, 271, 289
 effect of dam's immaturity upon, 274
 of dam's state of nutrition upon, 274, 275
 of underfeeding, 272, 280
 from birth, 279
 inheritance of, 151
 intra-uterine, 273
 later in life, 282
 prepotency and, 126
 regulation of, 85
Diarrhea, 268
 infectious, 258, 262, 268
Dinsmore, 131, 132
Dioestrus, 39
Dioestrus cycle, 39
Disease, inheritance of, 157
Domestic animals, classified, 194
Domestication of animals, 7, 168
 effect on man, 169
 fertility and, 241
 possibilities of further, 171
Dominance, 94, 124
Drag of the race, the, 120
Drosophila, sex determination in, 54
- E
- Economy in breeding operations, 290
Efferent ducts, 25
Egyptian agriculture, 171
 livestock breeders, 7, 145, 171
Ejaculation, 29
Ejaculatory ducts, 27

Ellenberger, 66
 Embryo nutrition, 61
 Environment, 83, 86, 138
 fertility and, 241
 sterility and, 246, 247
 Epididymis, 25
 Ernst, Mohler, and Eichorn, 76
 Establishing a breeding business, 284

F

Factor, 93
 Fallopian tubes, 31, 41
 cystic, 252, 258
 Fancy points, 216
 Fashion in bloodliness, 229
 Femininity and prepotency, 137, 220, 227
 Fertility, 235
 age and, 237
 of first breeding and, 238
 breed and, 236
 conformation and, 149, 243
 crossbreeding and, 243
 environment and, 241
 heredity and, 236
 importance of, 235
 inbreeding and, 190, 243
 lactation and, 242
 longevity and, 242
 nutrition and, 240
 variations and, 149
 Fertilization, 40, 49, 147
 Fibroid degeneration, 250
 Flushing, 38, 240
 Foal heat, 68
 Foetal membranes, 60
 nutrition, 61
 vascular system, 62
 Free-martin, 47, 250
 embryological study of, 49
 hormone theory of, 50

G

Galton, 115, 116
 Garfield, influence of, 129
 Gemmules, 87

Genealogy chart of a Holstein-Friesian family, 128
 of leading Percheron sires, 132
 of leading Standardbred sires, 134
 Genes, 18, 89, 93
 Genetics, defined, 2
 "Genetics in Plant and Animal Improvement," 2
 Genital organs, female, 29
 male, 23
 Genotype, 93
 Germinal epithelium, 32
 selection, 148
 Gestation, 59
 indications of, 59
 period of, 62
 variations of, 62
 Goiter, 269, 279
 Goodale, 56, 57
 Graafian follicle, 32, 35
 Grade, 178
 Grades, experience with, 288
 Grading, 205
 advantages of, 213
 beef cattle, 209
 chickens, 213
 dairy cattle, 207
 drawbacks of, 214
 hogs, 213
 Grading, horses, 206
 rapid improvement by, 205
 sheep, 212
 Gravidity (see Gestation)
 Growth, 15, 16, 17, 273
 determiner, 271
 Gudgell and Simpson, 177, 187

H

Haecker, 218
 Hairless pigs, 269, 279
 Hambletonian, 10, influence of, 134
 Hart, Steenbock, and Humphrey, 254, 275
 Heat (see Oestrus)
 Hereditary bridge, 91

Heredity, 80, 138
 control of, 91
 defined, 81
 determiners of, 87, 89
 development and, 85, 271, 279
 environment and training and, 83
 enzymes and, 91
 fertility and, 236
 importance of, 83
 Law of Ancestral, 120
 Mendel's law of, 93, 95
 physical basis of, 15, 18, 86
 theories of, 86
 Hereford, prepotency studies of, 129
 Hermaphrodite, 47
 Heterozygosity, 94
 Hinny, 201
 Holstein-Friesian, prepotency studies
 of, 126
 Homozygosity, 94
 Hormones, milk secretion and, 74, 76
 parturition and, 65
 secondary sex characters and, 58
 theory of the free-martin, 50
 Hunt, 127, 273
 Husky, 203
 Hybrids, 198, 202, 250

I

Idant, 87
 In-and-inbreeding, 184 (see Close-
 breeding)
 Inbreeding, 183, 243 (see Closebreed-
 ing)
 Incubation, 63
 period of, 63
 Infection, 161
 Infectious abortion, 255
 Inheritance, 18, 81
 defined, 81
 of disease, 157
 of unsoundness, 157
 of stature, 116, 118
 types of, 92
 blending, 92, 116 (see Blending
 inheritance)

Inheritance, types of, Mendelian, 92
 (see Mendelism)
 prepotent, 92, 124 (see Prepo-
 tency)
 Insemination, artificial, 42
 Intra-uterine development, 273
 Involution, 68

J

Joint ill, 268
 Jones, D. F., "Genetics in Plant and
 Animal Improvement," 2
 Judging livestock, 7

K

King of the Pontiacs, influence of, 127

L

Labor income, good crops and, 12
 good livestock and, 11, 12
 Lactation, 69
 blood supply for, 71
 colostrum, 69
 composition of farm animals' milk,
 69
 control of, 76
 fertility and, 242
 inciting cause of, 74
 nature's provision for the young, 69
 theories of, 72
 udder, anatomy of, 70
 Lactiferous ducts, 71
 Lantow, 239, 240, 274, 281
 Lewis, 44, 246
 Lillie, 48
 Linebreeding, 181 (see Closebreeding)
 Livestock and labor income, 11, 12
 numbers of, 10
 Lippincott, 213
 Living and non-living matter, differ-
 ences between, 15
 Lloyd-Jones and Evvard, 101, 103,
 110
 Longevity, fertility and, 150, 242
 Lord Morton's mare, 160
 Lovejoy, 189, 195
 Luciani, 73, 76

M

- McCandlish, Gillette, and Kildee, 207, 279
- McKerrow Farms, 189
- Malformations, 146
- Mal-presentations, 265
- Mammary vascular system, 71
- Mammitis, 270
- Marshall, 24, 39, 62, 76, 245
- Masculinity and prepotency, 137, 220, 227
- Masturbation, 246
- Maternal impressions, 162
- Maturation in females, 32
in males, 25
variation and, 147
- Mediastinum, 25
- Mehenwetre, Prince, 171
- Mendel, 92
- Mendel's objective, 93
- Mendelism, 92, 122
calculating an F_2 expectation, 99
complicated, 98
dominance, 94
lacking, 118
fixation of color by, 109
type by, 100
in cattle, Aberdeen-Angus, 114
color, 101
poled and horned, 94, 95, 97
in guinea-pigs, 98
in hogs, 109
in horses, 105
American Saddle Horse and, 115
color and, 105
in livestock, 98
in poultry, 113, 114
in sheep, color, 111
horned and hornless, 111
fleece characters, 123
law of, 93, 95
independent assortment of the genes, 96
segregation, 95
segregation not evinced, 118
multiple factor hypothesis of, 118
- Mendelism, need for studies of, 123
obstacles to studies of, 116
possibilities of, 113, 123
successive generations of hybrids, 95
terms of, 93
variations and, 148
- Metaphase, 18
- Metoestrum, 39
- Milk, average production by countries, 9
composition of, 69
fever, 270
production, increased by development, 279
by grading, 207
witches', 74
- Mitosis, 18
- Mule breeding, 198
chromosomes of, 200
fertility of, 198
generative organs of, 199
- Multiple factor hypothesis, 118
- Mumford, 46, 160, 272, 274, 280
- Mutations, 145
- Mutilations, 152

N

- Nervous influence on milk secretion, 74
- New-born, ailments of, 267
care of, 266
- New Salem Breeding Circuit, 294
- New York Mills Sale, 229
- Nick, 143
- Nucleoli, 17
- Nucleoprotein, 73
- Nucleus, 13, 16
- Nutrition, abortion and, 254, 275
development and, 272, 273, 274, 280
embryo, 61
fertility and, 240
foetal, 61
sex determination and, 53
sterility and, 247

O

- Oestrus, 36, 39
 - after conception, 45
 - duration of, 39
 - indications of, 39
- Oestrus cycle, 40, 65
- Oogenesis, 32
- Os uteri, 30
 - closure of, 250
- Outcrossing, 195
- Ovarian transplantation in chickens, 57
 - in guinea-pigs, 56, 158
 - in rats, 56
- Ovaries, 31
 - cystic, 77, 258
- Ovariectomy, effect of, 56
- Ovulation, 34, 41
 - time of, 41, 44
- Ovum, 32, 41
 - transplantation of, 158

P

- Pangenesis, theory of, 86
- Parturition, 64, 264
 - act of, 66
 - ailments of the dam, 269
 - assistance at, 265
 - care of the dam, 264, 265, 266
 - duration of, 66
 - in the bear, 68
 - inciting cause of, 65
 - indications of, 64, 264
 - involution after, 68
 - mal-presentations, 265
- Pedigree, fashion and, 229
 - individual and, 220, 228
 - kinds of, 232
 - judging, 231, 232
 - sale price and, 230
 - selection and, 228
- Penis, 29
- Percherons, prepotency studies of, 131
- Phenotype, 94
- Placenta, 60, 65, 76
- Pneumonia, 258
 - treatment for, 262

- Pock-like sores in new-born pigs and lambs, 269
- Polar bodies, 33
- Population and livestock numbers, 10
 - world increase in, 1, 10
- Puberty, 36
- Purebred defined, 178
 - livestock on farms, 8
- Pregnancy (see Gestation)
- Prepotency, 92, 124, 179
 - age and, 125
 - development and, 126
 - effect of early pregnancy on, 281
 - factors determining, 124
 - importance of, 126
 - in Aberdeen-Angus, 129
 - in Belgians, 133
 - in Clydesdales, 133
 - in Herefords, 129, 130
 - in Holstein-Friesians, 126
 - in Percherons, 131
 - in sheep, 124
 - in Shires, 133
 - in Shorthorns, 129, 131
 - in Standardbreds, 133
 - indications of, 136
 - individuality and, 130
 - sex and, 125
 - sex characters and, 137
 - vigor and, 126, 137
- Proestrus, 39
- Progression, 120
- Prophase, 18
- Prostate gland, 27
- Protoplasm, 13, 15, 16
- Pus cells in semen, 250

R

- Records, 289
- Regression, 119
- Reproduction, phases of, 23
- Reproductive organs, female, 29
 - male, 23
- Reticulum, 17
- Reversion, 144
- Ridgling, 249

- Rodney, a sire of show animals, 131
 Roland Cooperative Bull Association, 298
- S
- Sales, 291
 consignment, 296
 public, 292
 catalogs for, 292
- Sanders, 137
 Sanders and Dinsmore, 131
 Saturation, effect on inheritance, 161
 Schroeder, 259
 Scrub defined, 178
 sires, laws dealing with, 214
 Segis Pietertje Prospect, 141
 Segmentation, 42
 Segregation, law of, 95
 Selection, 215, 288
 act of, 220
 age and, 225
 breed of stock, 285, 287
 breeding test and, 220
 class of stock, 286
 constitution and, 227
 correlated characters and, 217
 fancy points and, 216
 farm, 285
 fashion and, 229
 Holstein-Friesians and, 215
 importance of, 215
 individual and, 223
 pedigree and, 228
 performance and, 227
 sex characters and, 227
 sires, 288
 type and, 223
 useful characters and, 215
 variations and, 155
- Seminiferous tubules, 25
- Sex, 52
- Sex characters, secondary, 55
 castration and ovariectomy, effect on, 56
 cause of, 55, 58
 recessive, 58
 transplanting sex cells and, 56
- Sex characters, determination, 52
 accessory chromosome theory of, 54
 age and vigor of parents, 52
 beyond control, 55
 nutrition and, 53
 time of mating and, 53
- Sexual overwork, 246
- Shaler, 168
- Smith, 34, 60, 65, 76
- Sni-a-Bar farm, grading beef cattle, 209
- Sore eyes in lambs, 268
- Spermatic fluid, 28
- Spermatids, 25
- Spermatocyte, 25
- Spermatogenesis, 25
- Spermatogonia, 25
- Spermatogonium, 25
- Spermatozoon, 26
 vitality of, 43, 44
- Stallion clubs, 299
- Sterility, 244
 abortion and, 254
 causes of, 245
 closure of the os uteri and, 250
 cryptorchids and, 249
 diseased reproductive organs and, 252
 environment and, 247
 exercise and, 246, 251
 fibroid degeneration and, 250
 free-martins and, 47, 250
 hybrids and, 250
 imperfect copulation and, 248
 improper feed and, 247
 masturbation and, 246
 obstruction of vas deferens and, 249
 overwork and, 248
 problem of, 244
 pus cells in semen and, 250
 services a male can perform, 246
 sexual overwork and, 246
 treatment of, 252
- Strangeway, 27, 29
- Superfoetation, 45

T

- Telegony, 159
- Telophase, 19
- Testicles, 23
- Thompson, 82
- Thumps, 268
- Tompkins, 177
- True-type Holstein-Friesians, 216
- Twin births, 45
- Type and production in chickens,
220
 - in dairy cows, 218
 - and selection, 223
 - changes in, 225

U

- Udder, anatomy of, 70
- Umbilical cord, 60
- Unsoundness, inheritance of, 157
- Urethra, 29
- Uterine milk, 61
 - seal, 59
 - sinuses, 60
- Uterus, 31
 - contractions of, 66
 - eversion of, 269
 - involution of, 68

V

- Vagina, 30
- Variation, 138, 215

- Variation, acquired characters and,
150, 159
 - causes of, 146
 - commonly believed, 159
 - external, 147, 154
 - internal, 147
 - classification of, 139
 - congenital characters and, 150
 - defined, 138
 - importance of, 139
 - in full sisters, 142
 - individual, 141
 - inheritance of, 146
 - selection and, 155, 156
 - sheep-dog and, 156
- Vas deferens, 23, 25, 27
 - obstruction of, 249
- Vascular anastomosis, 50
- Vesiculæ seminales, 27
- Vulva, 64

W

- Wakesha Co. Guernsey Breeders'
Association, 294
- Weismann, 87, 148, 153, 190
- Western Reserved Holstein-Friesian
Association, 294
- Wilson, 14, 18
- Whitehall Sultan, influence of, 129
- Wodsdalek, 33, 54, 200

Y

- Yolk-sac, 61

Author Winters, Laurence M. Agric. Stock W.
Title Animal breeding.

200561

DATE

University of Toronto
Library

DO NOT
REMOVE
THE
CARD
FROM
THIS
POCKET

Acme Library Card Pocket
Under Pat. "Ref. Index File"
Made by LIBRARY BUREAU

schubert

